

NASA Technical Memorandum 83259

NASA-TM-83259 19820010867

**LIMS Instrument Package (LIP) Balloon Experiment - Nimbus 7
Satellite Correlative Temperature, Ozone, Water Vapor, and
Nitric Acid Measurements**

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FEBRUARY 1982

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LIMS INSTRUMENT PACKAGE (LIP) BALLOON EXPERIMENT - NIMBUS 7 SATELLITE
CORRELATIVE TEMPERATURE, OZONE, WATER VAPOR, AND NITRIC ACID MEASUREMENTS

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SUMMARY

Between June 1978 and April 1979, the NASA Limb Infrared Monitor of the Stratosphere (LIMS) Instrument Package (LIP) balloon experiment was used to obtain correlative temperature, ozone, water vapor, and nitric acid data at altitudes between 10 and 36 kilometers. These data were obtained in order to assess the performance of the LIMS sensor flown on the Nimbus 7 Satellite. The LIP consisted of the NASA Wallops Flight Center modified electrochemical concentration cell ozonesonde, the NASA Lyndon B. Johnson Space Center ultra-violet absorption photometer for ozone, the British National Physical Laboratory water vapor infrared radiometric sonde, the National Center for Atmospheric Research (NCAR) chemical absorption filter instrument for nitric acid vapor, and the Institute D'Aeronomie Spatiale de Belgique infrared radiometer for nitric acid vapor.

This document contains descriptions of the LIP, its correlative sensors, and the resulting data obtained from an engineering flight and four correlative flights which were launched from Palestine, Texas, and Cold Lake, Alberta, Canada.

INTRODUCTION

On October 24, 1978, the Limb Infrared Monitor of the Stratosphere (LIMS) sensor was launched aboard the Nimbus 7 Satellite. From launch until June 4, 1979, its mission was to measure the vertical distributions of temperature (T), ozone (O_3), water vapor (H_2O), nitric acid vapor (HNO_3), and nitrogen dioxide (NO_2) between the upper troposphere (10 km) and the lower mesosphere (about 65 km for T, O_3) in the $84^\circ N$ to $64^\circ S$ latitudinal range. These measurements will be applied along with those of other Nimbus 7 sensors to determine the feasibility of mapping sources, sinks, and dispersion mechanisms of atmospheric species on a near global basis.

N82-18741 #

The LIMS sensor, described in detail in references 1 and 2, is a six-channel, limb-scanning radiometer which measured, simultaneously, the radiances emitted by five target gases.

The resulting measured radiances and inferred T, O₃, H₂O, HNO₃, and NO₂ profiles will be placed in archives and made available for scientific investigations. Prior to release, the LIMS data must be validated. With this in mind, the LIMS Correlative (groundtruth) Measurements Program (LCMP) was established to assess the quality of the data and to aid in the validation processes.

The correlative program goals are: (1) to use sensors which could satisfy the accuracy and resolution goals defined in table 1; (2) to conduct the correlative measurements within ± 2 degrees (great arc distance) and within ± 3 hours of the geographical locations and times of target LIMS sensor measurements, and (3) to conduct the correlative measurements from sites located on a near global scale. These goals were established by the LIMS Nimbus 7 experiment team (NET). To identify sensors which could satisfy these goals and the accuracy goals in table 1, the LIMS NET conducted an international survey of ongoing and developing upper atmospheric research activities. The survey was followed by requests to identify research groups for participation in the LCMP and for detailed information on their capabilities and planned activities. The responses indicated that balloon-borne sensors could provide measurements in the stratosphere where the bulk of the LIMS measurements would be made. Therefore, a special large balloon effort was incorporated in the LCMP.

The special large balloon effort included six different balloon experiments of which the LIMS Instrument Package (LIP) was designated the primary source of correlative data. The LIP activities consisted of an engineering flight, prior to the launch of the Nimbus 7, and four post-launch correlative flights.

The purpose of this document is to briefly describe the LIP experiment and to summarize the resulting data. No attempts are made to compare the LIP data with those from the LIMS sensor.

SYMBOLS

| | |
|------------------|--|
| ECC | electrochemical concentration cell |
| f | ozone mixing ratio |
| GMT | Greenwich mean time |
| GSFC | NASA Goddard Space Flight Center |
| HALDECOM | High Altitude Long Duration ECC Ozone Monitoring |
| HNO ₃ | nitric acid vapor |
| H ₂ O | water vapor |

| | |
|---------------|---|
| I | intensity of ozone attenuated light |
| I_0 | intensity of unattenuated light |
| IASB | Institute D'Aeronomie Spatiale de Belgique |
| JSC | NASA Lyndon B. Johnson Space Center |
| K | Kelvin temperature |
| k | Boltzmann's constant |
| km | kilometer |
| LIMS | Limb Infrared Monitor of the Stratosphere |
| LIP | LIMS Instrument Package |
| N | north |
| NASA | National Aeronautics and Space Administration |
| NCAR | National Center for Atmospheric Research |
| NET | Nimbus 7 Satellite experiment team |
| NO_2 | nitrogen dioxide |
| NPL | British National Physical Laboratory |
| NSBF | National Scientific Balloon Facility |
| O_3 | ozone |
| p | pressure |
| ppbv | parts per billion by volume |
| ppmv | parts per million by volume |
| S | south |
| T | temperature, °K |
| W | west |
| WFC | NASA Wallops Flight Center |
| WIRS | Water Vapor Infrared Radiometric Sonde |
| uv | ultraviolet |
| ℓ | length of uv absorption photometer chamber |

| | |
|---------------|-------------------------------------|
| σ | ozone photoabsorption cross section |
| μm | micrometer |
| % | percent |

NASA LIP INSTRUMENTATION

The LIP was designed and fabricated by the NASA Goddard Space Flight Center (GSFC). The payload weighed approximately 4900 newtons and was integrated into a 1.84 x 1.69 x 1.74 meter gondola. The payload consisted of five sensors, the GSFC 64-command and 50-kilobit telemetry system (described in reference 3), and the National Scientific Balloon Facility (NSBF) balloon and tracking systems (reference 4), as well as the gondola.

In figure 1, a front view of the LIP shows the lithium battery power system, the GSFC command and telemetry system, the JSC ultraviolet absorption photometer, the British National Physical Laboratory (NPL) water vapor infrared radiometer sonde (WIRS), and the Institut D'Aeronomie Spatiale de Belgique (IASB) infrared radiometer. The hat is included for scale. In figure 2, a right rear view shows the NCAR chemical absorption filter instrument, the NSBF balloon control and tracking system, and the high altitude long duration electrochemical concentration cell ozone monitoring (HALDECOM) system. In figure 3, a left rear view shows the liquid nitrogen bottles for the NCAR instrument nitrogen powered pumps, the JSC photometer, and the GSFC system.

The LIP was carried into the stratosphere by 0.15 million cubic meter balloons up to altitudes as high as 36 kilometers. In figure 4, the photograph shows the LIP and balloon shortly before the October 30, 1978, launch from the NSBF at Palestine, Texas. During the first two flights, a standard electrochemical concentration cell (ECC) ozonesonde was mounted on the LIP next to the HALDECOM as shown in figure 4. This standard ECC is hereinafter referred to as the "captive ECC." In the foreground of figure 4, the LIP is mounted on the Ascent 2 payload launch vehicle, and in the background, the inflated balloon is secured to the balloon spool vehicle. Figures 5 through 10 show scenes typical of the launch operations.

Table 2 lists the characteristics of the LIP sensors. A nitrogen dioxide detector was originally planned for the LIP; however, commitments to another balloon experiment precluded its use on the LIP. In table 3, the LIP balloon experiment team is listed. In the following paragraphs, descriptions are given for each of the five sensors.

HALDECOM

The NASA Wallops Flight Center high altitude long duration ECC ozone monitoring (HALDECOM) system is a modified standard ECC ozonesonde. It was designed to be used on large balloons to measure in situ O_3 concentrations on the ascent from the surface up to 40 km and on the descent down to 10 km. It differs from the standard ECC, described in detail in references 5 and 6, in that its anode and cathode have three times the volume of the standard ones. This modification allows the sampling times to be increased from 2 hours,

covering the typical standard ECC ascent, to 6 to 8 hours covering the ascent and descent phases of large balloons. During flight, the HALDECOM is physically and electronically coupled to a standard NOAA radiosonde (references 7 and 8) which measures temperature and pressure. The relative humidity measurements are made between the surface and 10 km.

UV Absorption Photometer

The JSC ultraviolet absorption photometer is designed to measure in situ O_3 concentrations between 10 to 44 km from a balloon platform.

The photometer, described in reference 9, is a modified Dasibi which uses the strong ozone absorption of the 253.65 nanometers wavelength light. The basic operation of the photometer is illustrated in figure 11. Ambient air is pumped into the instrument through the gas sample inlet and is distributed along paths A and B. Along path A, ozone-rich air is pumped to a gas switching port which allows samples from either path A or B to enter the absorption chamber. Along path B, the air sample is pumped through a filter which selectively removes ozone. After leaving the filter, the essentially ozone depleted air sample is pumped to the gas switching port. The absorption chamber has two windows which are optically transparent to wavelengths of the incident mercury light source. The light source is a low-pressure, mercury vapor lamp which emits 253.65 nanometers wavelength light. The source light is projected on the first window X, cocked at an angle of 45 degrees to the incident light direction. Part of the light is reflected by the window X to detector 1, and the other part is transmitted through the window into the absorption chamber where it passes through the sample air, leaves through window Y, and then is projected on detector 2. Detector 2 measures the intensity of the incident light not absorbed by ozone in the air sample. Detector 1 integrates the light reflected from window X to determine when a predetermined number of photons has been emitted by the light source. Once that number has been reached, the air sample is flushed out and another sample is pumped into the chamber. This process is alternately performed for samples from paths A and B.

The ozone number density is determined using the following equation

$$[O_3] = (I_0 - I) / \ell \sigma I_0$$

where I_0 is the reference intensity of the light passing through the ozone depleted sample from path B, I is the intensity of the ozone attenuated light passing through the ozone-rich sample from path A, ℓ is the length of the chamber, and σ , is the ozone photoabsorption cross section. The ozone mixing ratio f , is obtained using

$$f = kT (I_0 - I) / P \ell \sigma I_0$$

where k , is the Boltzmann's constant, T , is the temperature of the air sample and P , is the air pressure in the chamber.

WIRS

The British National Physical Laboratory, WIRS, is a single-channel radio-meter which detects atmospheric thermal emissions from the H_2O rotation band

in the 30 to 300 μm wavelength region. As shown in figure 12, the emissions are collected within a 3 degree field-of-view by a small Cassegrain telescope and projected upon a TGS pyroelectric detector. The WIRS is typically set at an elevation angle of 45 degrees from the vertical during flight. On the ascent, the WIRS remotely measures water vapor between 10 km up to altitudes slightly above 30 km.

NCAR Chemical Absorption Filters

The National Center for Atmospheric Research (NCAR) chemical absorption filter balloon-borne sensor can measure in situ HNO_3 vapor concentrations in the 37 to 17 km altitudinal range during the balloon descent. The technique, described in references 10 and 11, uses filters composed of cellulose fibers coated with dibutoxyethylphthalate to collect HNO_3 vapors. During flight, sample filters are exposed to predetermined volumes of ambient air over several different altitudinal ranges while the reference filters are masked to prevent HNO_3 collection. The exposure time for each sample filter is dependent upon the descent rate and upon the ambient air pressure. The flight instrument consists of a 20-filter carousel and its pump is driven by an air ejection pump which utilizes compressed nitrogen as a primary gas.

After flight, the unmasked samples are subjected to chemical analyses to determine the amount of HNO_3 collected. Visible spectrophotometry is used to determine the HNO_3 collected on the filters. The masked reference samples are analyzed to establish zero HNO_3 levels.

IASB Infrared Radiometer

The IASB sensor is a circular variable filter infrared radiometer which can be used to determine remotely HNO_3 vapor concentrations from atmospheric emissions in the 7 to 15 micron wavelength region. An earlier version of the radiometer is described in reference 12. In the radiometer, atmospheric emissions are collected in a 14 degrees wide and 4 degrees high field of view by Irtran 4 optics. The collected emissions pass through an OCLI circular variable filter which makes the wavelength selection, and are finally projected upon a pyroelectric detector. The total amount of HNO_3 is determined from the differences between the atmospheric emissions and reference emissions from a cylindrical chopper operating at a known and stabilized temperature. The concentrations are inferred from scan measurements made at elevation angles of -2, 0, +2, +8, and +55 degrees. The radiometer is sensitive to nitric acid in the 1 to 100 ppbv mixing ratio range.

LIP FLIGHT RESULTS

Between June 1978 and April 1979, the LIP activities consisted of an engineering and four LIMS correlative balloon flights from the NSBF (31°31'N, 95°42'W) near Palestine, Texas, and from the Canadian Air Forces Base (54°46'N, 110°03'W) near Cold Lake, Alberta, Canada. During the first two flights, the captive standard ECC ozonesonde was flown on the LIP to evaluate the performance of the HALDECOM. During each LIP flight, standard ECC's flown on separate smaller balloons (referred to as "free flyers"), and ground-based Dobson type spectrophotometers were used to obtain complementary ozone profiles and total overburden, respectively.

Engineering Flight

On June 5, 1978, the LIP was launched for its first flight at 1404 GMT from Palestine, Texas. This engineering flight provided stratospheric T, O₃, and H₂O profiles between 17 and 35 km. HNO₃ profiles were not obtained. The NCAR HNO₃ filter data could not be converted to mixing ratios because the volumes of air flowing through the filters were not properly recorded. The IASB radiometric measurements for HNO₃ exhibited poor signal-to-noise ratios and could not be reliably reduced.

In figures 13 and 14, the resulting flight trajectory, T, O₃ mixing ratios, and H₂O vapor mixing ratios profiles are presented for the WFC HALDECOM, captive, free flyer, JSC photometer, and NPL WIRS sensors. In figure 13(a), the trajectory emphasizes the facts that the sensor measurements were obtained on the ascent up to 35 km and on the descent between 35 and 20 km, and that the typical LIP flight would last approximately 6 hours.

In figure 13(b), the comparison of the ascent T profiles generated by the HALDECOM and captive ECC shows good agreement between the profiles. In figure 13(c), representative descent T profiles obtained from two free flyers are compared. The comparison shows good agreement. The free flyers were launched at 1752 and 1753 GMT from Palestine, approximately 0.5 degree north of the LIP descent location, and provided T profiles within 2 hours of the LIP descent. For comparison of the temperatures in the vicinity of the LIP descent with those of the ascent, representative free-flyer data were used because the HALDECOM descent T and O₃ data were not available. The HALDECOM descent data could not be reduced using existing ascent data reduction techniques. Comparisons of the ascent and descent profiles indicate good agreement up to 33 km. Above 33 km, the ascent data were found to be higher than those of the descent.

In figure 14(a), the HALDECOM, captive ECC, and JSC photometer O₃ mixing ratios are presented for the LIP ascent. Comparisons of the profiles indicate good agreement up to 31 km where at higher altitudes the HALDECOM data are found to be lower. Up to 30 km, the HALDECOM and captive measurements are found to be typically 0.5 and 0.3 ppmv higher than those of the JSC sensor, and they suggest that the ozone peaked at altitudes lower than those indicated by the photometer results. The total O₃ overburdens inferred from the integrated HALDECOM and captive profiles were found to be 286 and 275 Dobson units, respectively, compared to the 275 reference value measured using the ground-based Dobson-type, New Zealand (Canterbury) Filter Ozone Spectrophotometer (Ref. 13) above Palestine.

In figure 14(b), the descent O₃ mixing ratios from the JSC sensor are compared to those from the two 1752 and 1753 GMT flyers. The comparisons show fair agreement up to 30 km where at higher altitudes the free flyers' data are found to be as much as 2 to 3 ppmv higher. It is believed that the atmosphere, near Palestine, had a higher O₃ content than the atmosphere 0.5 degree south of Palestine, where the LIP descent occurred. The fact that the JSC sensor ascent and descent data exhibited no discernible differences, and that the Canterbury measured a higher O₃ overburden of 311 Dobson units near the LIP descent time than it measured during the LIP ascent time, 275 Dobson units, tends to support the above belief.

As in the ascent comparisons, the free-flyers (constructed almost identically to the HALDECOM and captive ECC) ozone data were found to be consistently higher than those from the JSC sensor. These observed differences suggest a bias between ozone data generated by the JSC sensor and the ECC type sensors.

In figure 14(c), the WIRS H₂O mixing ratios are presented for the LIP ascent altitudes between 10 and 20 km. The ratios were found to be within the 1.6 to 4.8 ppmv range suggested for the stratosphere by reference 14. For altitudes between 20 and 30 km, the data could not be reduced because the accuracy of the WIRS external blackbody reference source became degraded when its temperature due to solar heating became unacceptably high. Prior to subsequent LIP flights, the sensor was redesigned and additional thermal shielding was added to compensate for the higher solar heating.

The JSC photometer was the only LIP sensor not to experience problems during the engineering flight. The HALDECOM exhibited a shift in its reference level which was caused by low input voltages from it to the GSFC telemetry system. The problem was resolved by shortening the input voltage cable in order to reduce the voltage drop in the cable, thereby increasing the input voltage to the telemetry system. The captive ECC exhibited RF interference in its data caused by the GSFC telemetry system. The captive ECC had a 1680 MHz telemetry system separate from the GSFC one. The interference was eliminated by reeling the captive system antennae 15.24 meters below the LIP gondola.

The NCAR chemical absorption filter instrument measured HNO₃ amounts for several altitudinal intervals. However, from the filter data, it was not possible to calculate concentrations because the air flow rates through each filter were not properly recorded. The frequencies of the air flow meter were too high to be handled by the GSFC telemetry system. This problem was resolved by converting the frequencies to voltages which were compatible with the telemetry system. The IASB radiometer did not yield usable HNO₃ data because of poor signal-to-noise ratios. Therefore, the radiometer was modified to reduce its chopper frequency by 50 percent to improve the signal-to-noise ratios. In addition, the spectrum scanning rate was reduced by a factor of 4 to collect more data points at each wavelength.

The above modifications to the sensors were performed prior to the LIP correlative flights.

LIMS Correlative Flights

On October 30, 1978, November 8, 1978, February 8, 1979, and April 6, 1979, the LIP was successfully launched to obtain LIMS correlative T, O₃, H₂O, and HNO₃ profiles. The February 8, 1979, launch was conducted from Cold Lake while the other three were conducted from Palestine. The sensors, with the exception of the IASB radiometer, produced usable profiles. The IASB radiometer raw data were not reduced to final form because the new data form from the modified radiometer was found not to be compatible with the existing IASB data reduction procedures.

In figures 15 and 16, the October 30, 1978, flight trajectory, T, O₃, and HNO₃ profiles are presented from the WFC HALDECOM captive free-flyer (Ref. 15), JSC photometer (Ref. 9), and NCAR chemical absorption filter sensors. Water data were not obtained because the WIRS was not turned on. In figure 15(a), the flight trajectory indicates that the correlative measurements were obtained within 6 hours and 2.5 degrees of the 0511 GMT October 31, 1978, LIMS measurements which were conducted to the west of Palestine. Closer time coincidence with the LIMS measurements was not possible because increases in the surface wind speed above 9 km/hr (maximum launch speed) prevented a launch much after the 2215 GMT LIP launch time.

In figure 15(b), the HALDECOM and captive ECC ascent T profiles are presented for the 10 and 34 km altitudinal range. The comparison shows good agreement. In figure 15(c), the representative descent T profiles obtained from a free flyer are presented. On October 31, 1979, the free-flyer was launched at 0304 GMT from Palestine and its data were obtained 3.3 degrees to the west of the LIP descent location. Between 20 and 30 km, the free flyer profile is found to be approximately 2 degrees lower than those of the HALDECOM and captive profiles but still within the accuracies of their thermistors.

In figure 16(a), the ascent HALDECOM, captive, and JSC photometer O₃ mixing ratios are compared. The comparisons show good agreement among the profiles for the three sensors. As in the case of the June 5, 1978, flight comparisons, the HALDECOM and captive mixing ratios were typically higher (0.9 and 0.4 ppmv, respectively) up to 31 km and indicate that the O₃ peaked at a lower altitude than those of the JSC photometer. The HALDECOM and captive profiles inferred O₃ overburdens of 260 and 244 Dobson units, respectively, compared to the 272 reference value measured over Palestine using the Dobson type, ground-based Sentran 4 Filter Optical Photometer, designed similar to the optical rocket ozonesonde (Ref. 16).

In figure 16(b), the descent JSC photometer and free-flyer O₃ mixing ratios are compared. The free-flyer data were obtained approximately 3.3 degrees to the west of the LIP descent. The free-flyer data were found to be typically 0.6 ppmv higher than those of the JSC sensor; however, the agreement between the two profiles was good considering their accuracy envelopes. The free-flyer profile inferred an O₃ overburden of 258 Dobson units compared to the reference 272 value obtained by the Sentran 4. There were no noticeable differences between the ascent and descent profiles from the JSC sensor.

In figure 16(c), the NCAR chemical absorption filter HNO₃ mixing ratios are presented for the LIP descent. The HNO₃ ratios agree with typical mixing ratios of 2 ppbv near 18 km and 5 ppbv maximum near 24 km suggested by reference 17 for mid-latitudes.

The November 8, 1978, LIP flight experiment represented the first time that all of the LIP parameters of T, O₃, H₂O, and HNO₃ data were measured successfully during a flight. The results from this flight are presented in figures 17 and 18. The HALDECOM free-flyer, and JSC photometer results were taken from references 15 and 9, respectively. As indicated in figure 17(a), the 1620 GMT launch allowed measurements to be obtained within 4 degrees and within 3 hours of the 1904 GMT LIMS measurements. During this and subsequent flights, the captive ECC sensor was not flown because the HALDECOM was found

to perform satisfactorily during the two earlier flights. Therefore, the captive was no longer needed for HALDECOM evaluations.

In figures 17(b) and 17(c), the HALDECOM ascent and the free-flyer representative descent T profiles are presented. There appear to be no discernible differences between the profiles. The free flyer was launched at 1850 GMT from Palestine and its data were obtained approximately 0.6 degree to the west of the LIP descent location.

In figure 18(a), the ascent HALDECOM and JSC photometer O₃ mixing ratios are compared. Between 21.5 and 31.5 km, the HALDECOM profile is found to be typically 0.9 ppmv higher and to indicate that the ozone peaked at lower altitudes than the JSC photometer profile. This trend was observed during the previous LIP flights. In figure 18(b), the comparison of the JSC sensor and free-flyer descent O₃ data shows that the free-flyer data were as much as 3 ppmv higher at the high altitudes. The free-flyer results were obtained approximately 0.6 degree to the west of the LIP descent. The higher free-flyer data appear to be reasonable considering the fact that the O₃ inferred overburden of 317 Dobson units was found to be higher than the 277 Dobson units inferred from the HALDECOM ascent profile and the 286 value, representative of the ascent, measured using the Sentran 4. The fact that there were no discernible differences observed between the ascent and descent JSC sensor profiles indicates that the atmosphere around the LIP descent had lower ozone concentrations than the atmosphere near Palestine where the free-flyer measurements were obtained.

In figure 18(c), the WIRS H₂O and NCAR HNO₃ mixing ratios are presented. The H₂O mixing ratios are found to be in good agreement with the 1.6 to 4.8 ppmv range suggested by reference 14. However, the profile is found to be 1.0 to 3.5 ppmv higher than the June 5, 1978, WIRS profile and almost identical to the WIRS profile obtained on November 2, 1978, during a University of Minnesota balloon flight launched from Palestine.

The NCAR HNO₃ results fall within the range suggested by reference 17 for mid-latitudes and are almost identical to the October 30, 1978, flight results.

The 1715 GMT February 8, 1979, LIP launch from Cold Lake represented perhaps a record for the largest balloon launched as far north as 54 degrees N at the coldest temperature 236 degrees K. For this flight, HALDECOM results are not presented because a malfunction of its pump caused the resulting O₃ data to be an order of magnitude lower than those observed from free flyers. For this flight, resulting T, O₃, and HNO₃ profiles are presented in figures 19 and 20. The O₃ and T profiles were taken from references 9 and 18.

In figure 19(a), the flight trajectory points out that the correlative measurements were obtained within 4 degrees and within 4 hours of the 2024 GMT LIMS measurements. In figures 19(b) and 19(c), representative ascent and descent T profiles are presented from free flyers launched at 1702, 2007, and 2327 GMT from Primrose Lake, Canada (54°48'N, 110°05'W), located 0.03 degree to the northwest of Cold Lake. The comparisons of the profiles indicated no discernible differences. For altitudes up to 25 km, these profiles indicate essentially constant temperatures and 5°K to 25°K warmer temperatures than those observed during the earlier Palestine LIP flights.

In figures 20(a) and 20(b), JSC photometer and free-flyer O_3 mixing ratios are compared for the LIP ascent and descent. In both figures, the free-flyer data are found to be in good agreement with those of the JSC sensor between 12 and 22.5 kms. Above 22.5 km, the free-flyer results were found to be as much as 1.0 to 1.2 ppmv higher for the ascent and descent, respectively. Both types of sensors measured similar O_3 structure at essentially the same altitudes. The O_3 mixing ratios show O_3 peaking at lower altitudes than those observed during earlier Palestine flights. The free-flyers were launched at 1702, 2007, and 2327 GMT from Primrose Lake and obtained measurements approximately 0.03° , 1.00° , and 1.50° to the northwest of the LIP location. The total O_3 overburdens inferred from the free-flyer units, were found to be considerably higher than the 244 to 317 range observed during the LIP flights conducted near Palestine for the late spring 1978 and early fall 1978.

In figure 20(c), the WIRS H_2O and NCAR $HN O_3$ mixing ratios are presented. Between 12 and 24 km, the H_2O results fall within the 1.6 to 4.8 ppmv range. Above 24 km, the agreement is fair within this range, considering the 50 percent accuracy envelope of the WIRS sensor. Below 18 km, the agreement between this high-latitude profile and the mid-latitude November 8, 1978, one is excellent. Above 18 km, the high-latitude profile is found to be 1.5 to 5.7 ppmv higher than the mid-latitude one. This observation may indicate an increase of H_2O with increasing latitudes toward the pole at altitudes above 18 km.

The $HN O_3$ high-latitude profile indicated higher mixing ratios than the previous two mid-latitude profiles obtained near Palestine. This observation is in agreement with the conclusion of Lazrus and Gandrud (reference 19) that $HN O_3$ concentrations should increase from the equatorial to polar latitudes.

On April 6, 1979, the LIP flight produced T, O_3 , and $HN O_3$ profiles. H_2O data were not obtained because the WIRS was damaged during the ground phase of the 0055 GMT LIP launch. The IASB radiometer was not flown on the LIP. In figures 21 and 22, T and O_3 data are presented from references 20 and 9, as well as $HN O_3$ data.

In figure 21(a), the flight trajectory points out the fact that the correlative measurements were performed within 2.5 degrees and within 3.5 hours of the target 0514 GMT LIMS measurements. In figures 21(b) and 21(c), ascent HALDECOM and a representative descent free-flyer T profiles are presented. The ascent and descent profiles were found to be in good agreement from 10 up to 34.5 kms. The free-flyer was launched at 0613 gmt from Palestine and obtained T measurements approximately 0.5° to the southwest of the LIP descent location.

In figures 22(a) and 22(b), the HALDECOM, the 0613 GMT free-flyer, and the JSC photometer O_3 mixing ratios are compared. The ascent HALDECOM and representative descent flyer profiles were found to be higher typically by 0.9 and 0.5 ppmv, respectively, than those of the JSC sensor between 21 and 30 km. This trend was observed in each of the earlier flight comparisons of the ECC type sensors and the JSC one. The inferred O_3 overburdens from the HALDECOM and flyer profiles were found to be 360 and 347 Dobson units, respectively, compared to the corresponding 338 and 347 values measured using the ground-based Sentran 4. The early spring 1979 overburden

measurements were found to be significantly higher than the 224 to 317 Dobson units range observed during the previous late spring 1978 and early fall 1978 LIP flights launched from Palestine, and they indicate a spring maximum for ozone.

In figure 22(c), the NCAR HNO_3 mixing ratios are presented. The early spring 1979 profile is slightly lower than profiles obtained during the early fall 1978 LIP flights launched from Palestine. This trend is not consistent with the observations of Lazrus et al (Ref. 19) where they suggest higher concentrations in the winter and spring than in the summer and mid-fall.

CONCLUSIONS

Between October 30, 1978, and April 6, 1979, the LIP balloon experiment successfully provided stratospheric, correlative T, O_3 , H_2O , and HNO_3 data for the assessment of the quality of the LIMS/Nimbus-7 Satellite sensor data products. The correlative data were obtained within 2.5 to 4.0 degrees and within 3 to 6 hours of the geographical locations and times of target LIMS measurements.

The ECC type ozone sensors were found to measure slightly higher ozone mixing ratios than the JSC photometer. Both types of ozone sensors provided good correlative data in the 10 to 35 km altitudinal range.

The NPL WIRS sensor measured H_2O mixing ratios in the 0.5 to 7.6 ppmv range between 12 and 30 km.

The NCAR chemical absorption filter sensor provided HNO_3 mixing ratios in the 0.3 to 6.4 ppbv range in the 16 to 35 km altitudinal interval.

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TABLE 1. - Correlative Measurements Accuracy Goals

| Stratospheric Parameter | Accuracy Requirement | Altitude Region (Km) | Altitude Resolution (Km) |
|----------------------------|-------------------------|-------------------------|-----------------------------|
| T | 0.5°K | 10 - 70 | 2 |
| O ₃ | 10 - 20% | 10 - 60 | 2 |
| H ₂ O | 20 - 30% | 10 - 50 | 4 |
| HN ₃ | 30% | 10 - 40 | 2 |
| NO ₂ | 30% | 10 - 40 | 4 |

TABLE 2.- Characteristics of the LIP Sensors

| Sensor | Measurement | Technique | Accuracy | Resolution |
|--|-----------------------------|--|----------------------------------|------------|
| WFC HALDECOM | | | | |
| Thermistor | In situ T | Resistance thermometry | 1.0°K @ surface 2.5°K @ 30 Km | 0.5 Km |
| Aneroid baroswitch | P | Differential pressure | | |
| Electrochemical Concentration Cell | In situ O ₃ | Electro-chemistry | | |
| <hr/> | | | | |
| JSC UV absorption photometer | In situ O ₃ P | UV absorption photometry Differential pressure | 8% 2.1% | 0.5 Km |
| <hr/> | | | | |
| NPL | Remote H ₂ O | Infrared emission spectrophotometry | 50% | 2.0 Km |
| <hr/> | | | | |
| NCAR Chemical Absorption Instrument | In situ HNO ₃ | Chemical analysis of samples collected by filtration | 12% | 3.2 Km |
| <hr/> | | | | |
| IASB Radiometer | Remote HNO ₃ | Infrared emission spectrophotometry | | 2.0 Km |

TABLE 3.- LIP Balloon Experiment Team

| Function | Individual | Agency |
|---|-------------------|--------|
| LIP Manager | Edmund F. Szajna | GSFC |
| LIP Engineer | Fred M. Witten | GSFC |
| HALDECOM Investigator | Laurence C. Rossi | WFC |
| UV Absorption Photometer Investigator | Donald E. Robbins | JSC |
| WIRS Investigator | Nigel R. W. Swann | NPL |
| Chemical Absorption Filter Investigator | Bruce W. Gandrud | NCAR |
| Radiometer Investigator | Carlos Lippens | IASB |

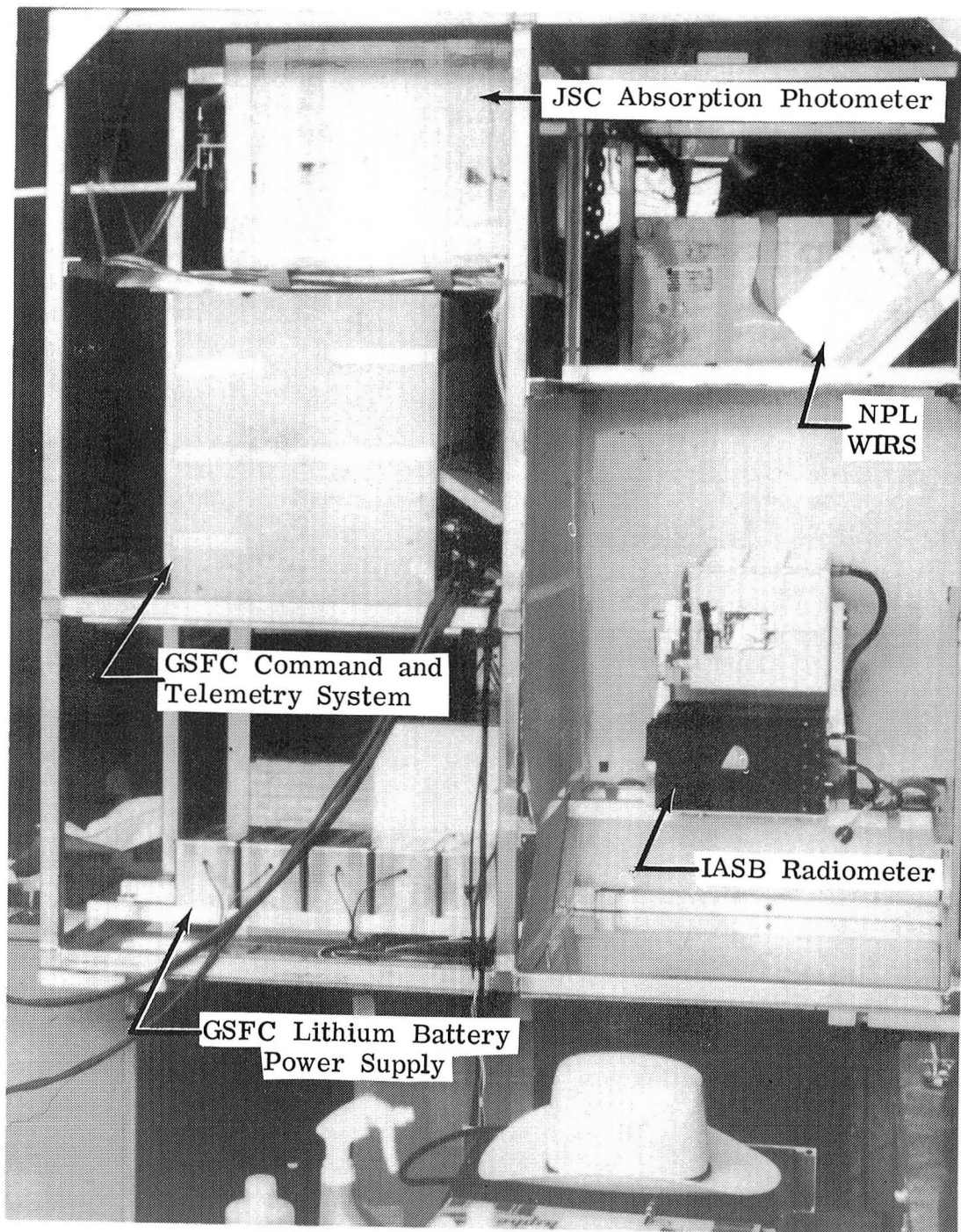


Figure 1.- Front view of the LIP.

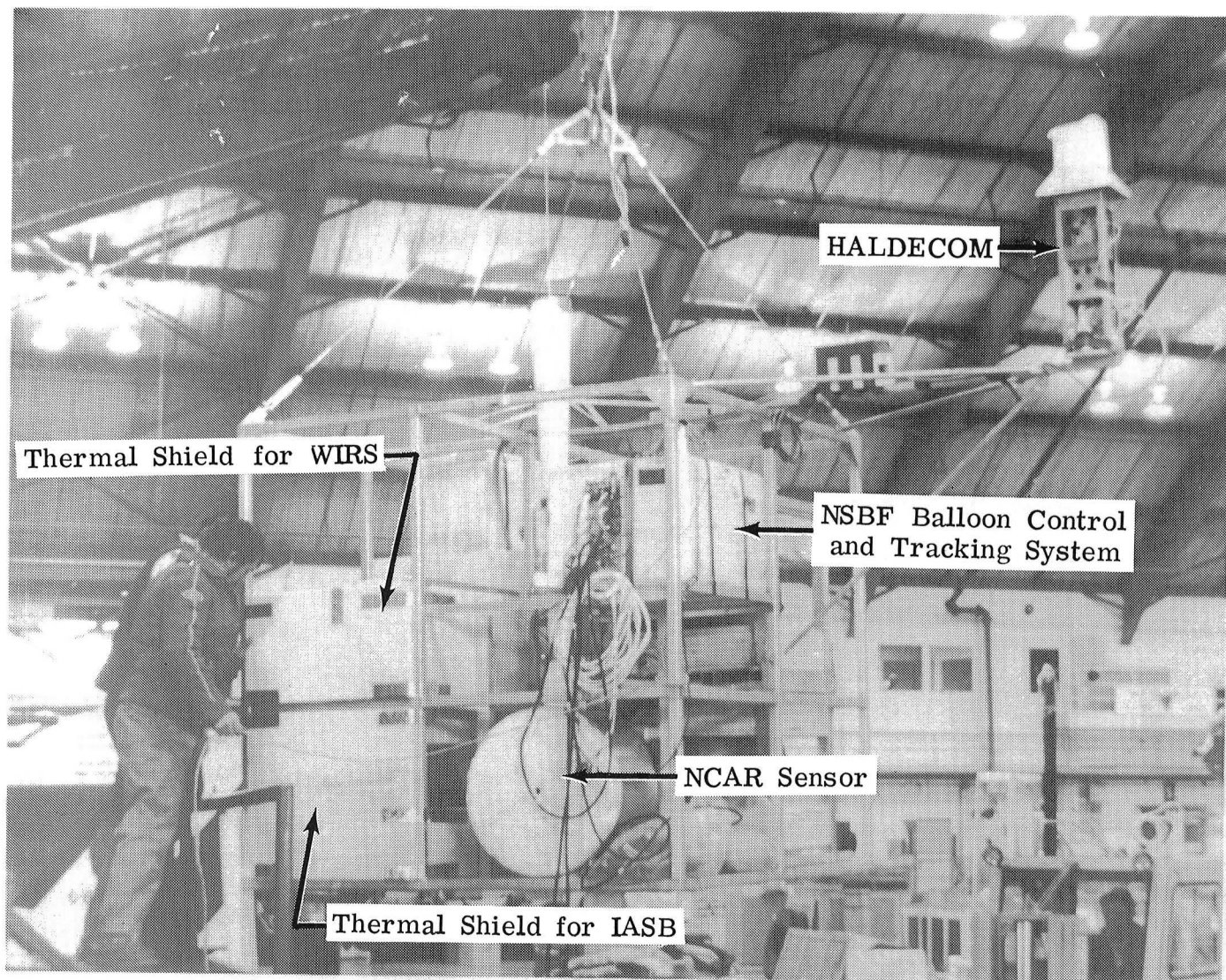


Figure 2.- Right rear view of the LIP.

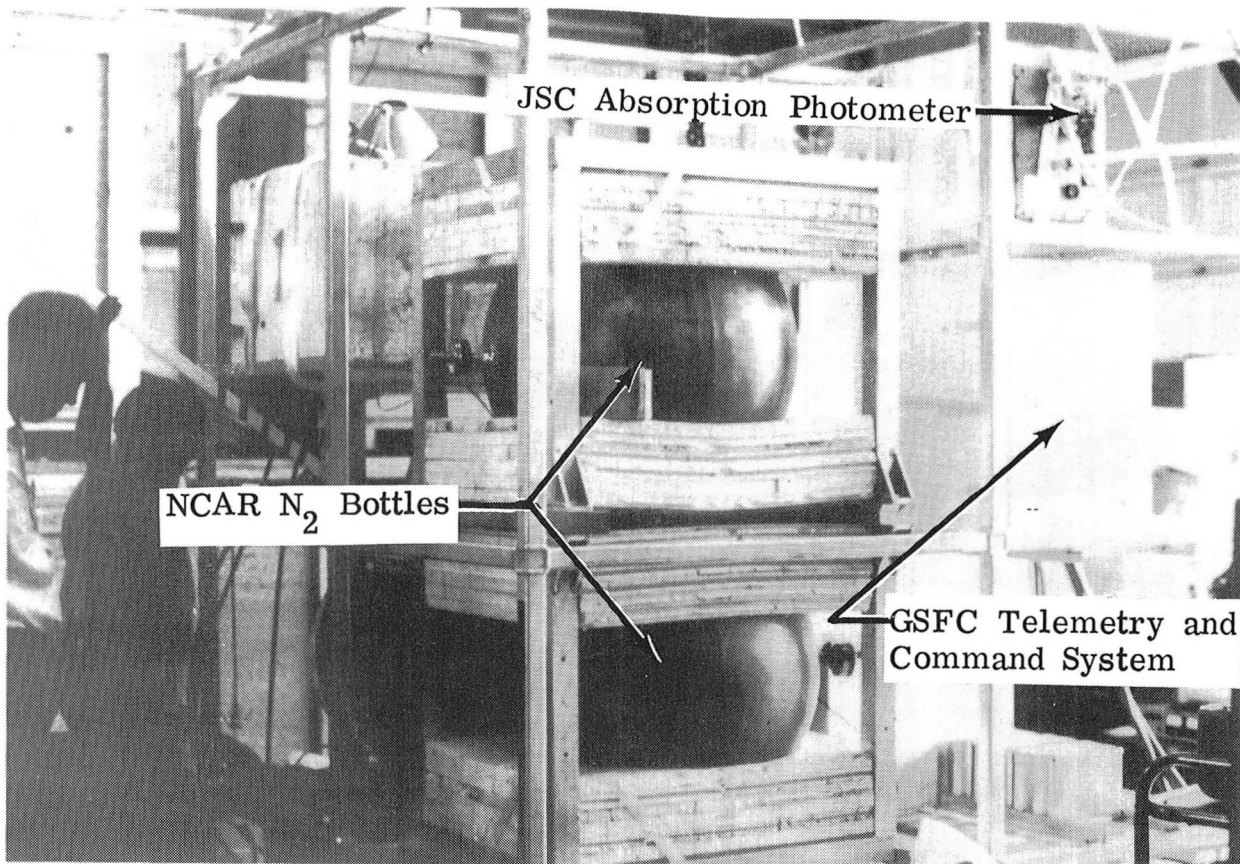


Figure 3.- Left rear view of the LIP.

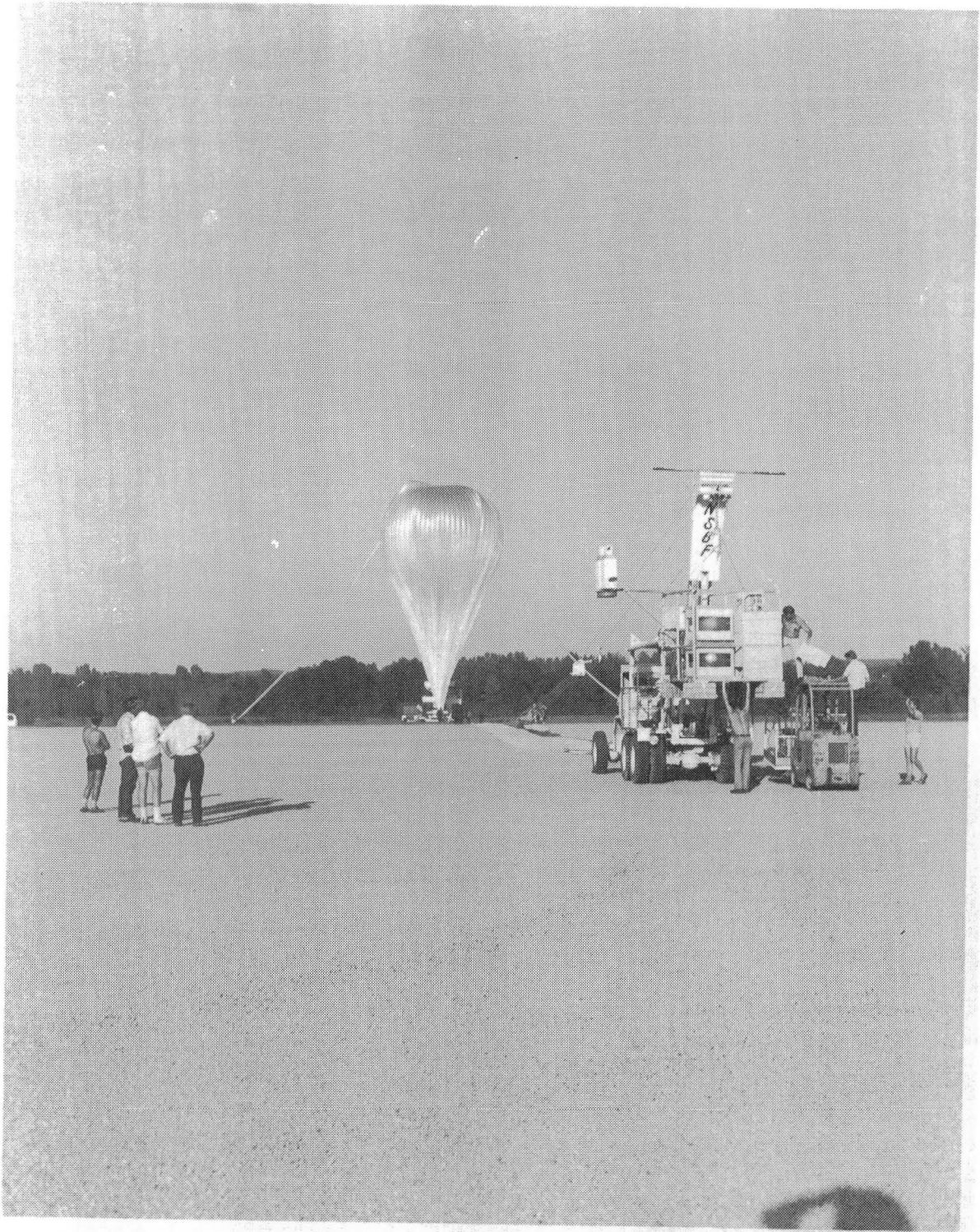


Figure 4.- Shown is the LIP being prepared for its October 30, 1978, launch from the National Scientific Balloon Facility. In the foreground, the LIP is secured to the Ascent 2 launch vehicle. In the background, the balloon is secured to balloon spool vehicle.



Figure 5.- The LIP payload is shown ready for its October 30, 1978, launch with the balloon being inflated.

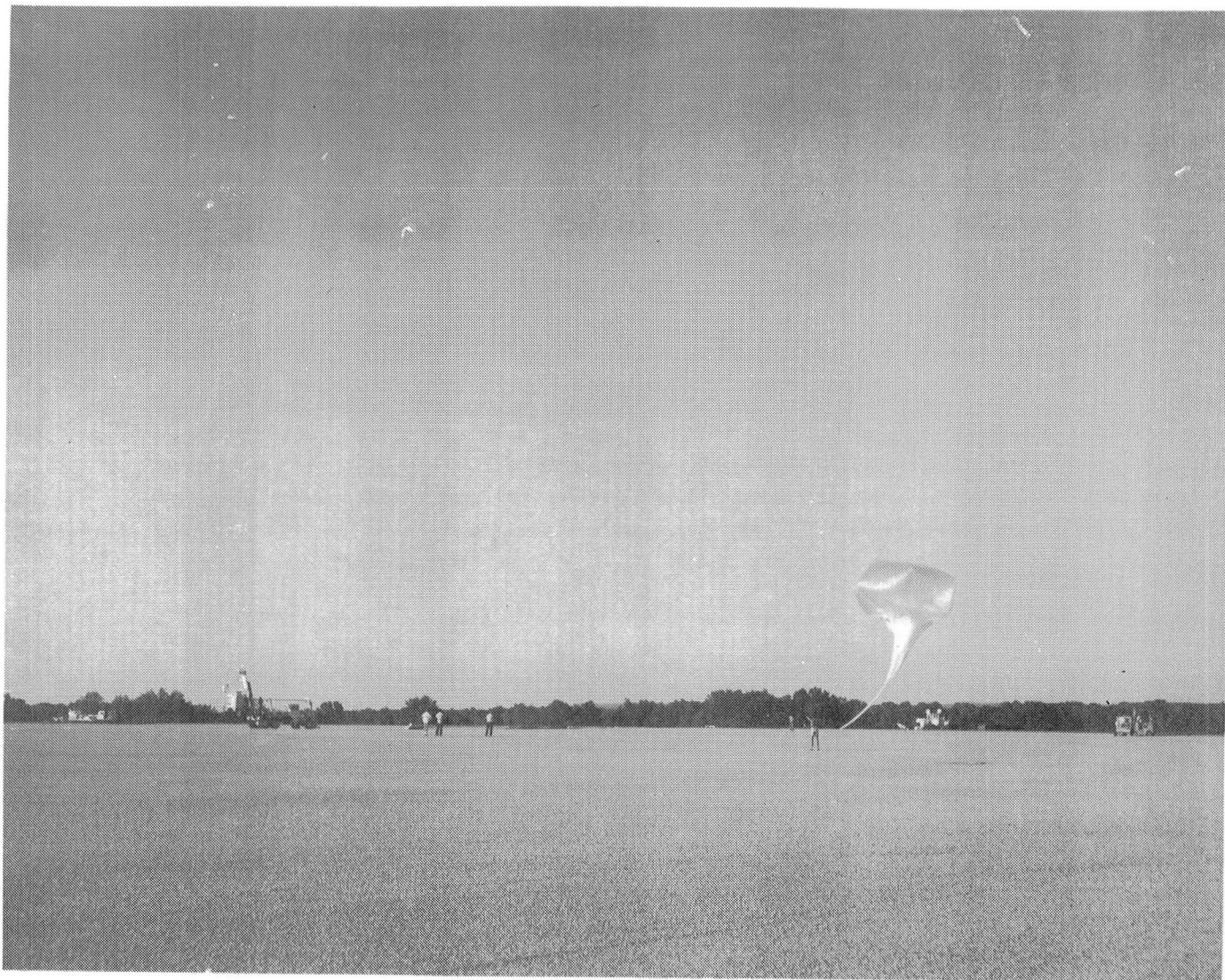


Figure 6.- The balloon is released to start the launch process.

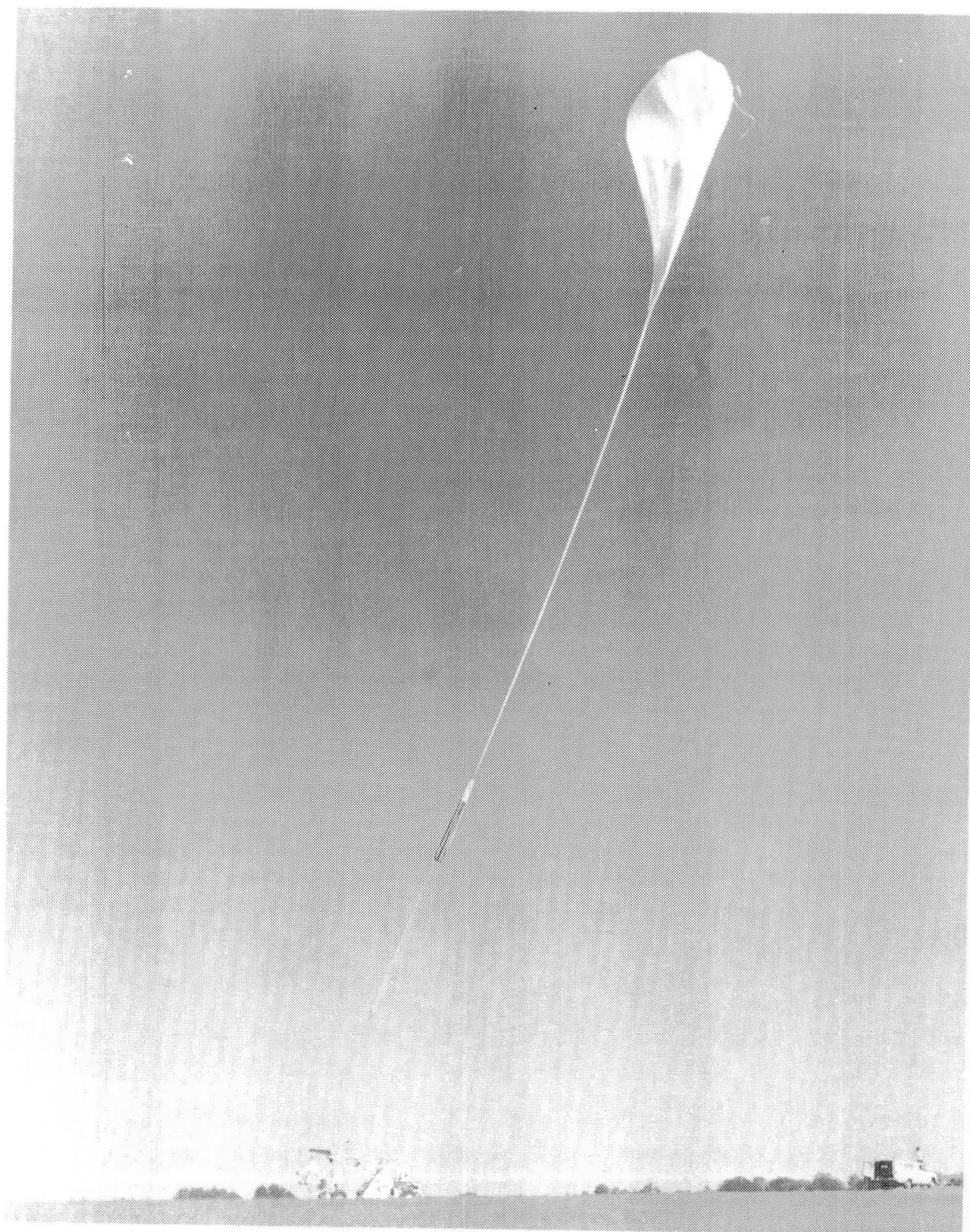


Figure 7.- Before the LIP launch, the launch vehicle maneuvers to align the LIP directly under the balloon.

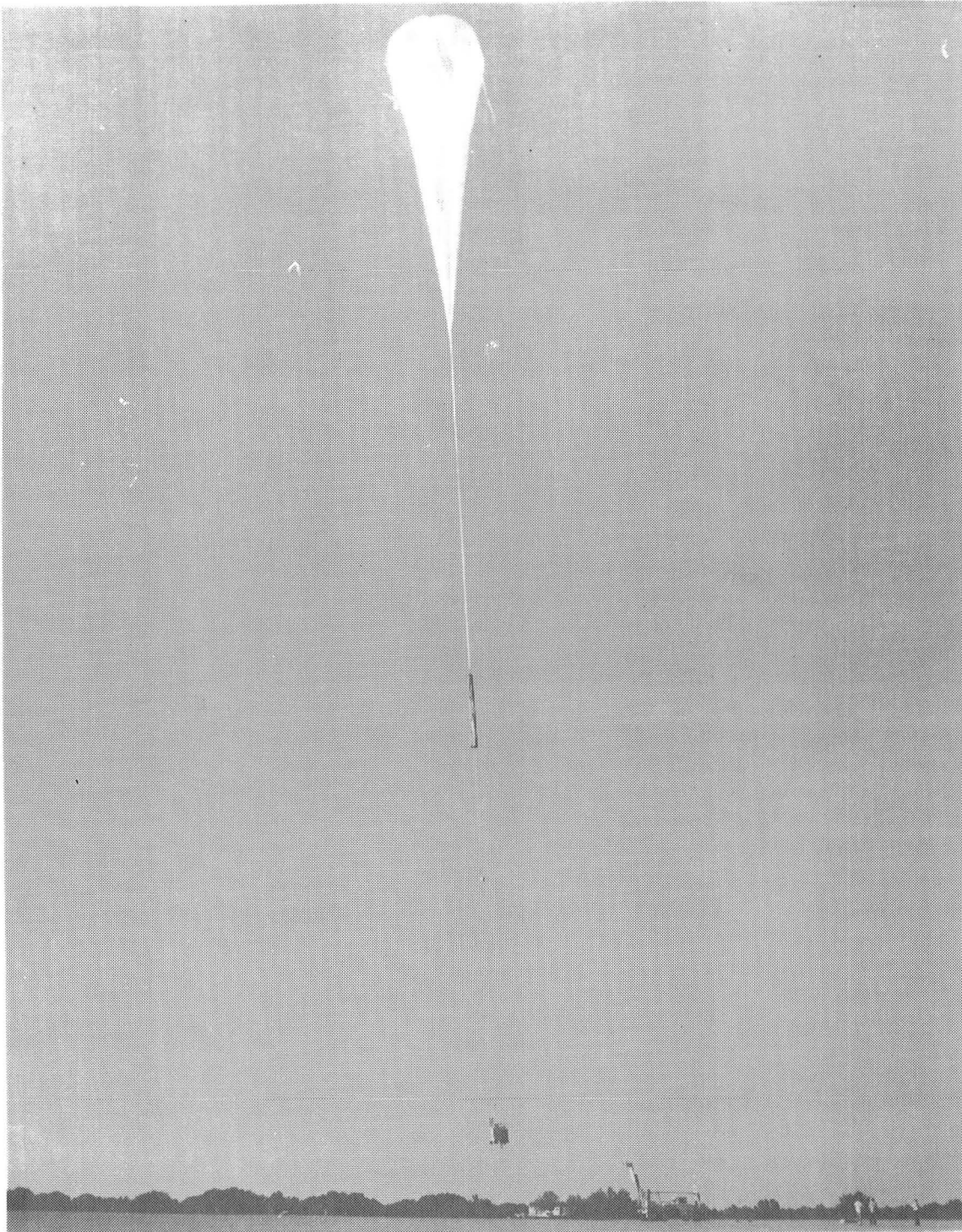


Figure 8.- The LIP is launched and the launch vehicle backs away from the payload.

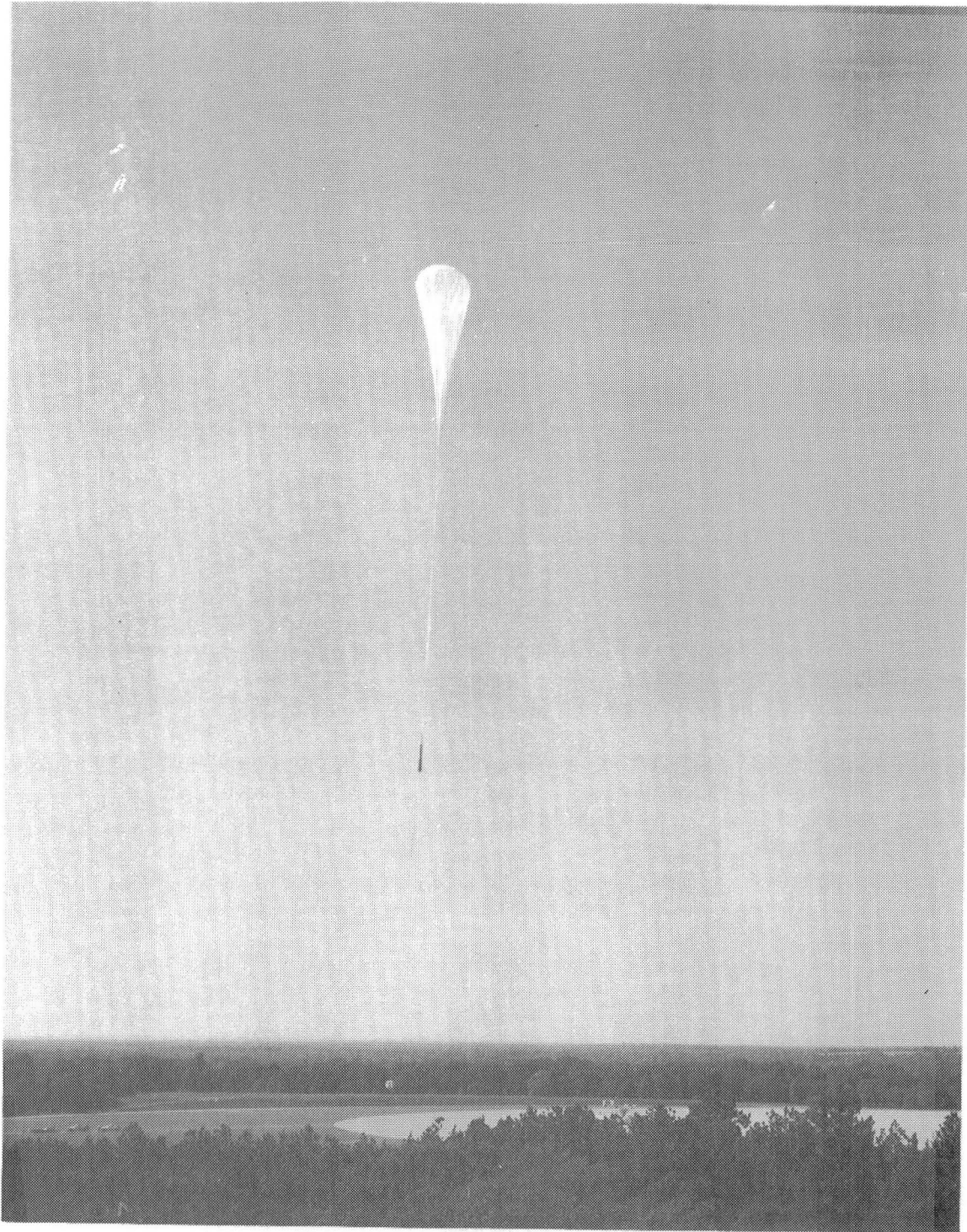


Figure 9.- The LIP clears the launch pad.

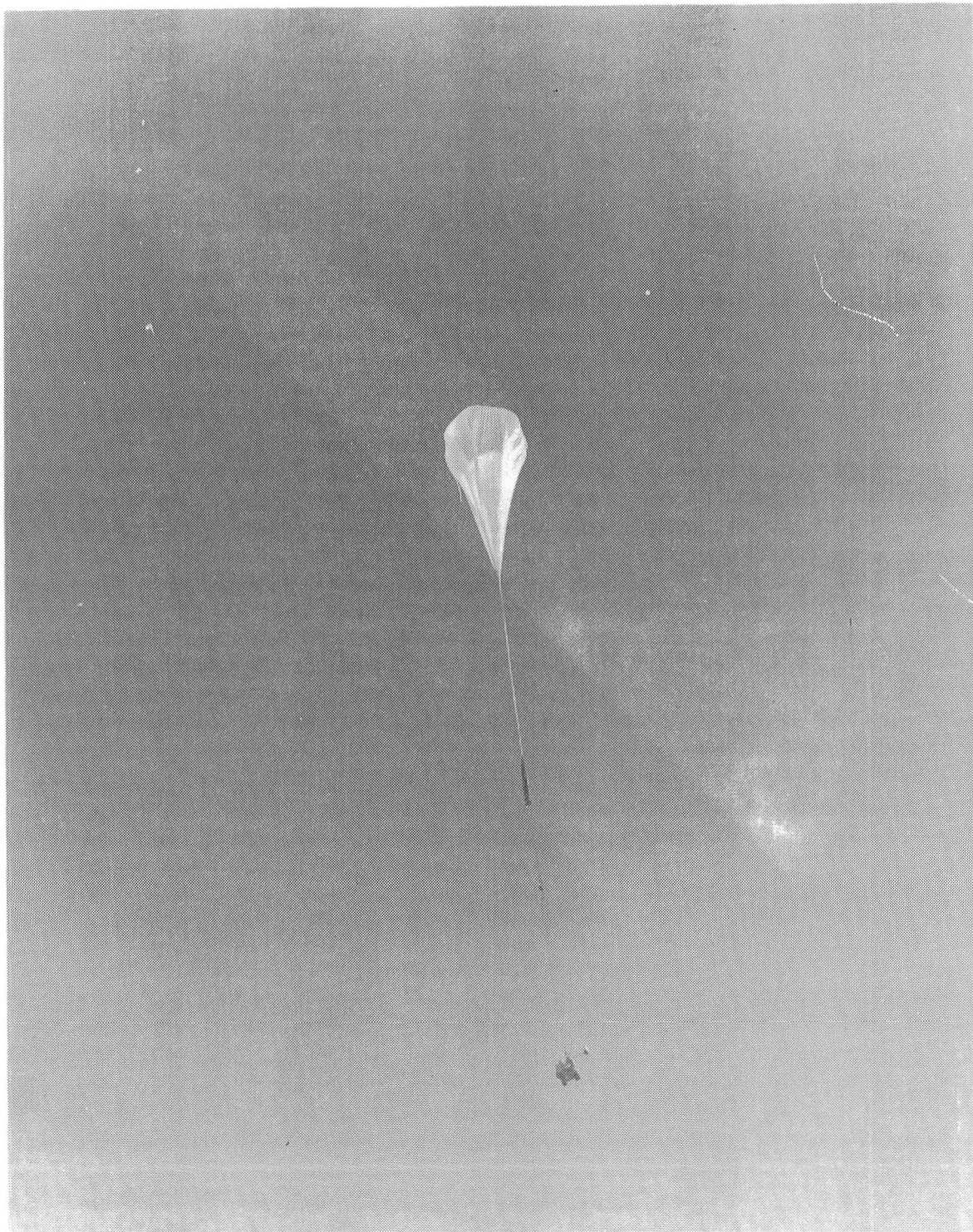


Figure 10.- The LIP ascends to the stratosphere for a rendezvous with the LIMS experiment.

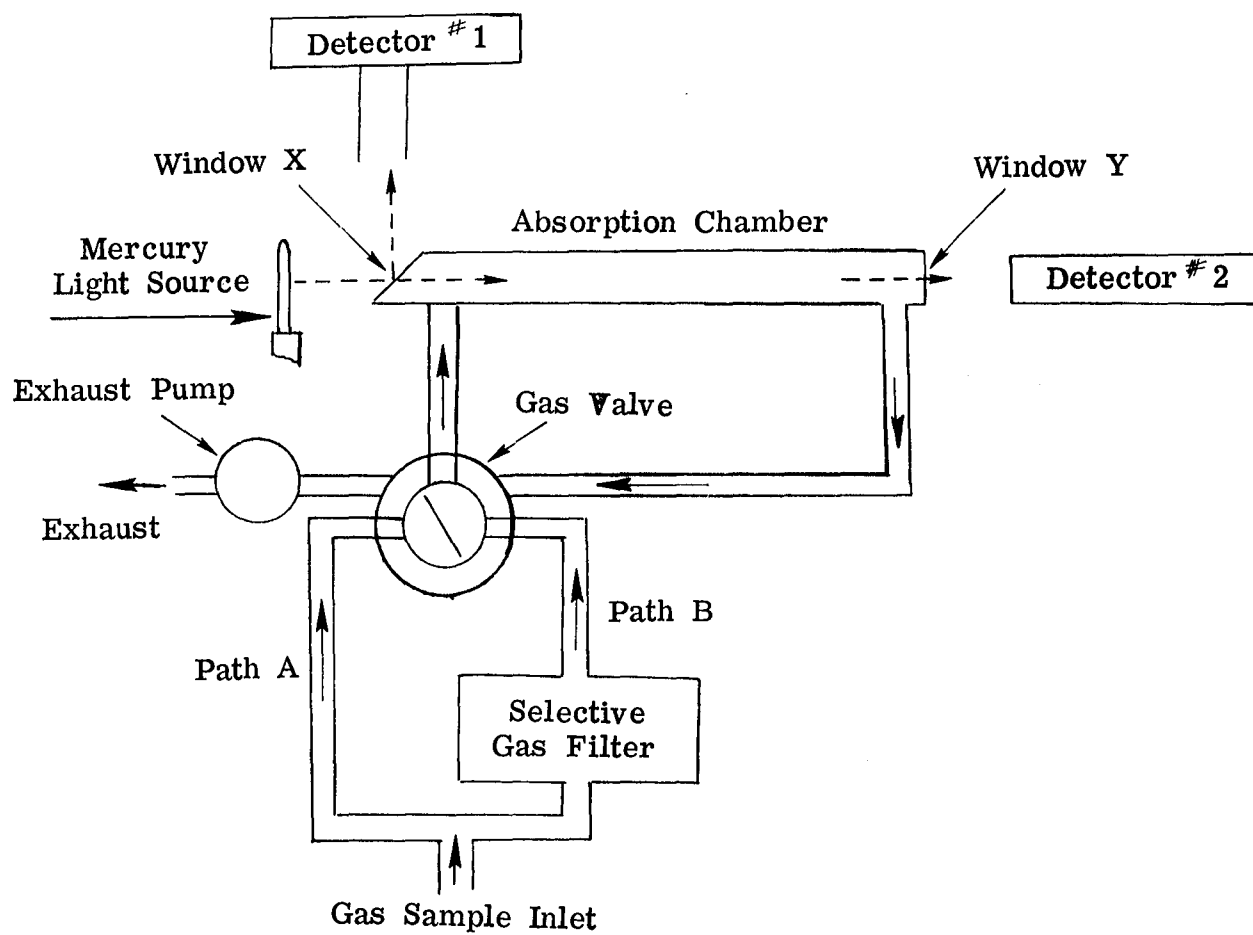


Figure 11.- Block diagram of UV Spectrophotometer.

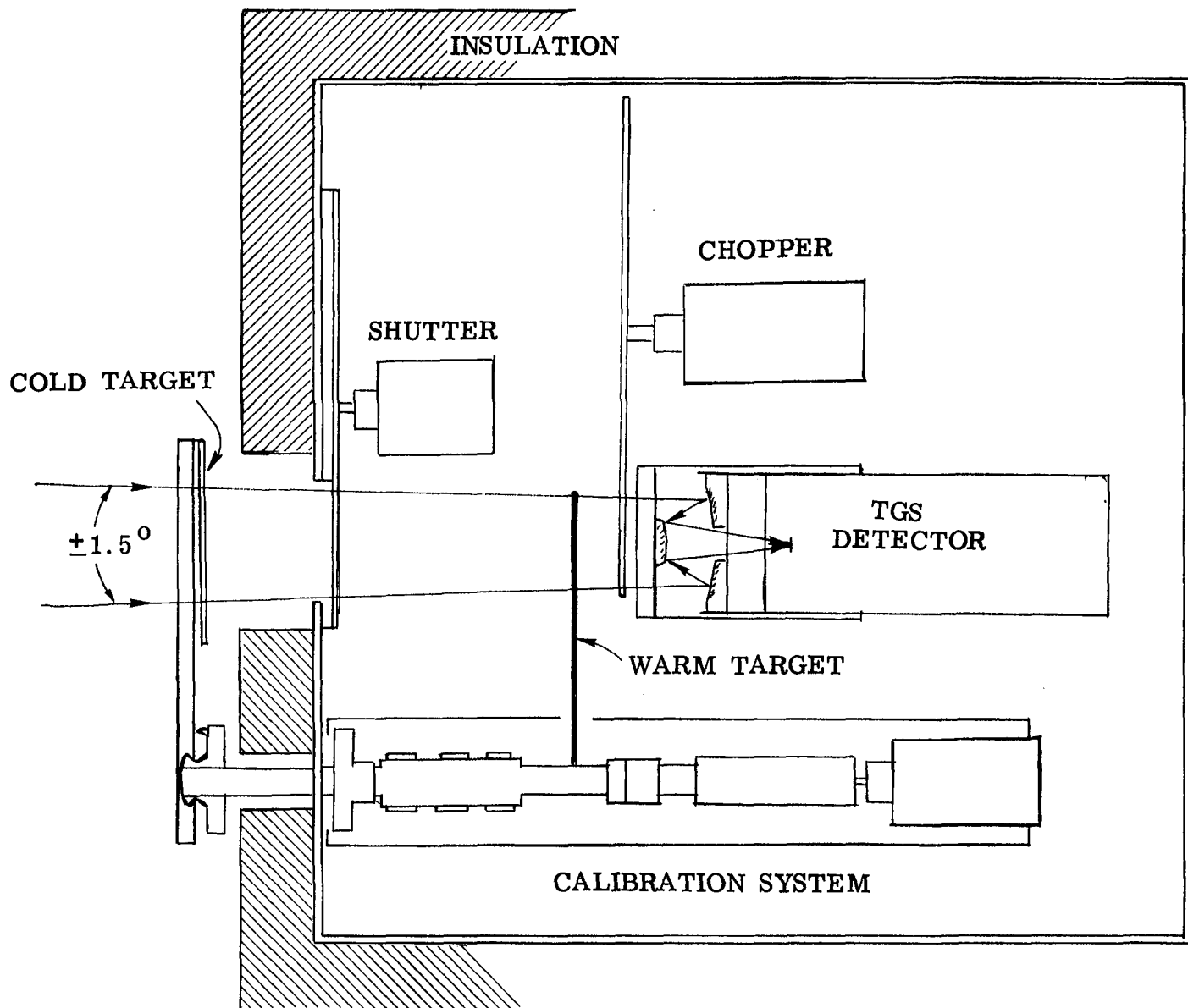


Figure 12.- WIRS schematic diagram.

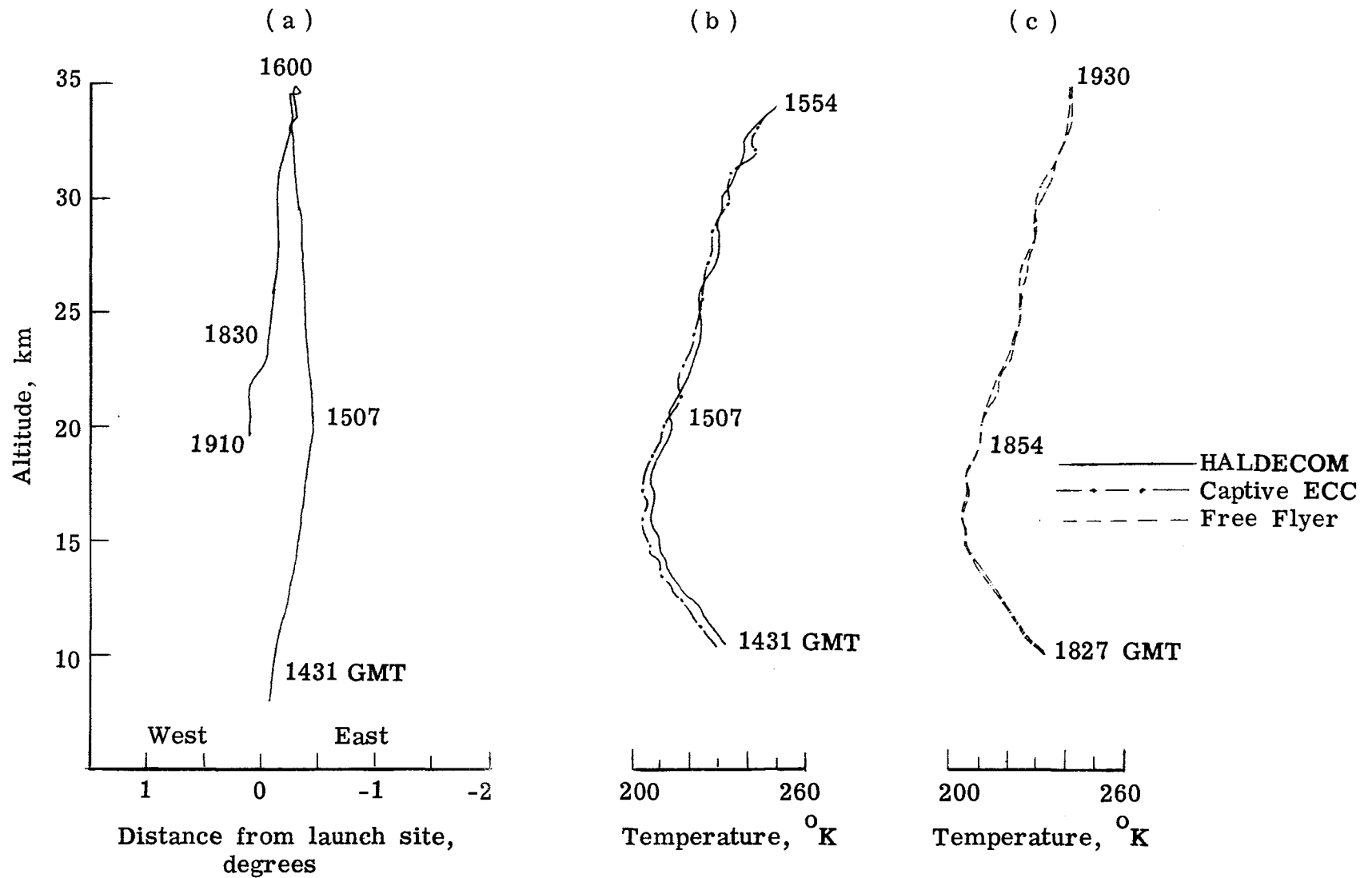


Figure 13.- For the June 5, 1978, LIP flight, shown are the (a) LIP flight trajectory relative to Palestine, (b) ascent HALDECOM and captive ECC temperature profiles, and (c) representative LIP descent temperature profiles obtained from free flyers launched at 1752 and 1753 GMT from Palestine.

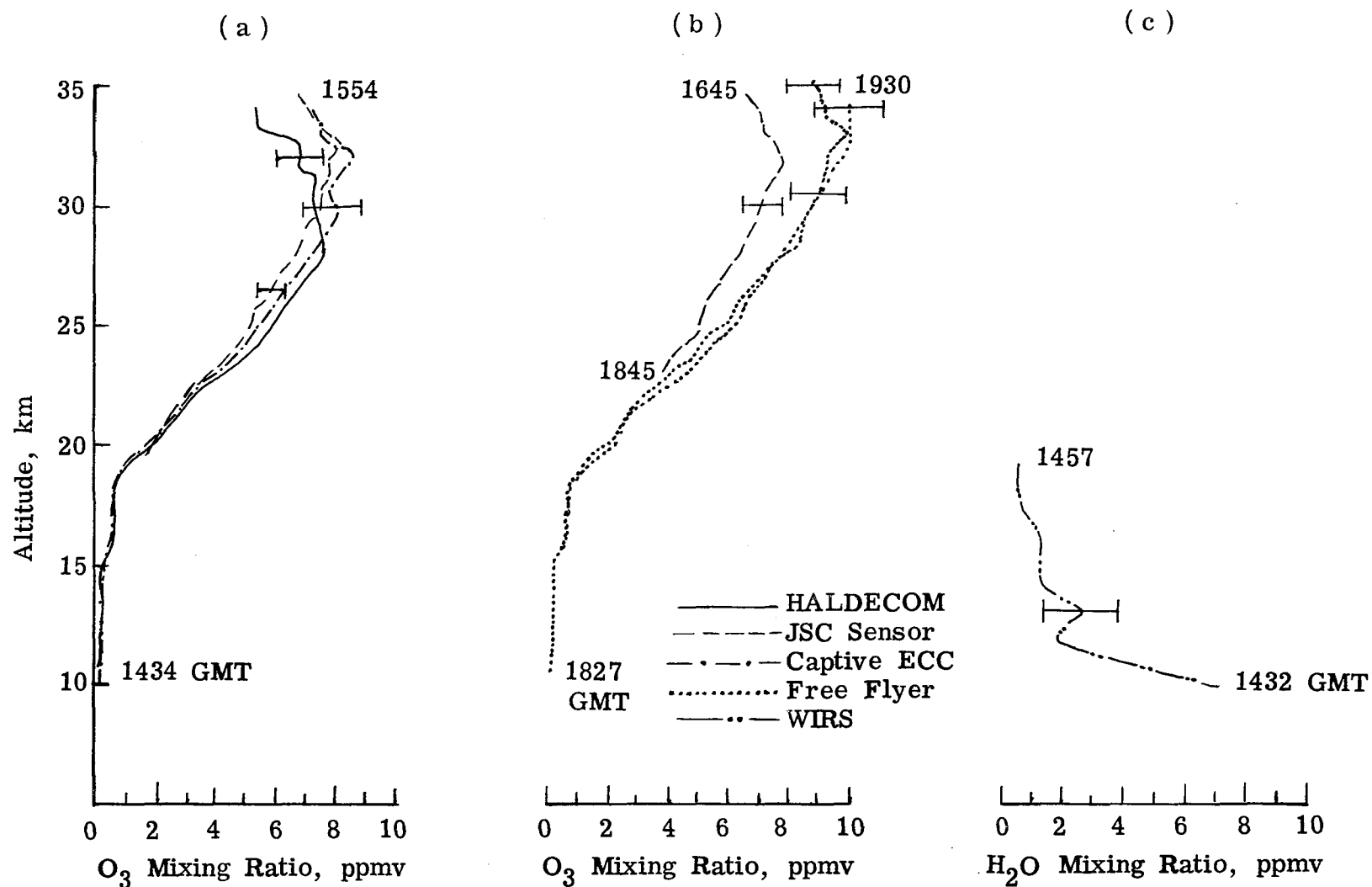


Figure 14.- For the June 5, 1978, LIP flight, shown are the (a) ascent HALDECOM, captive ECC, and JSC photometer O₃ mixing ratios, (b) descent JSC photometer and free flyers O₃ mixing ratios, and (c) WIRS H₂O vapor mixing ratios.

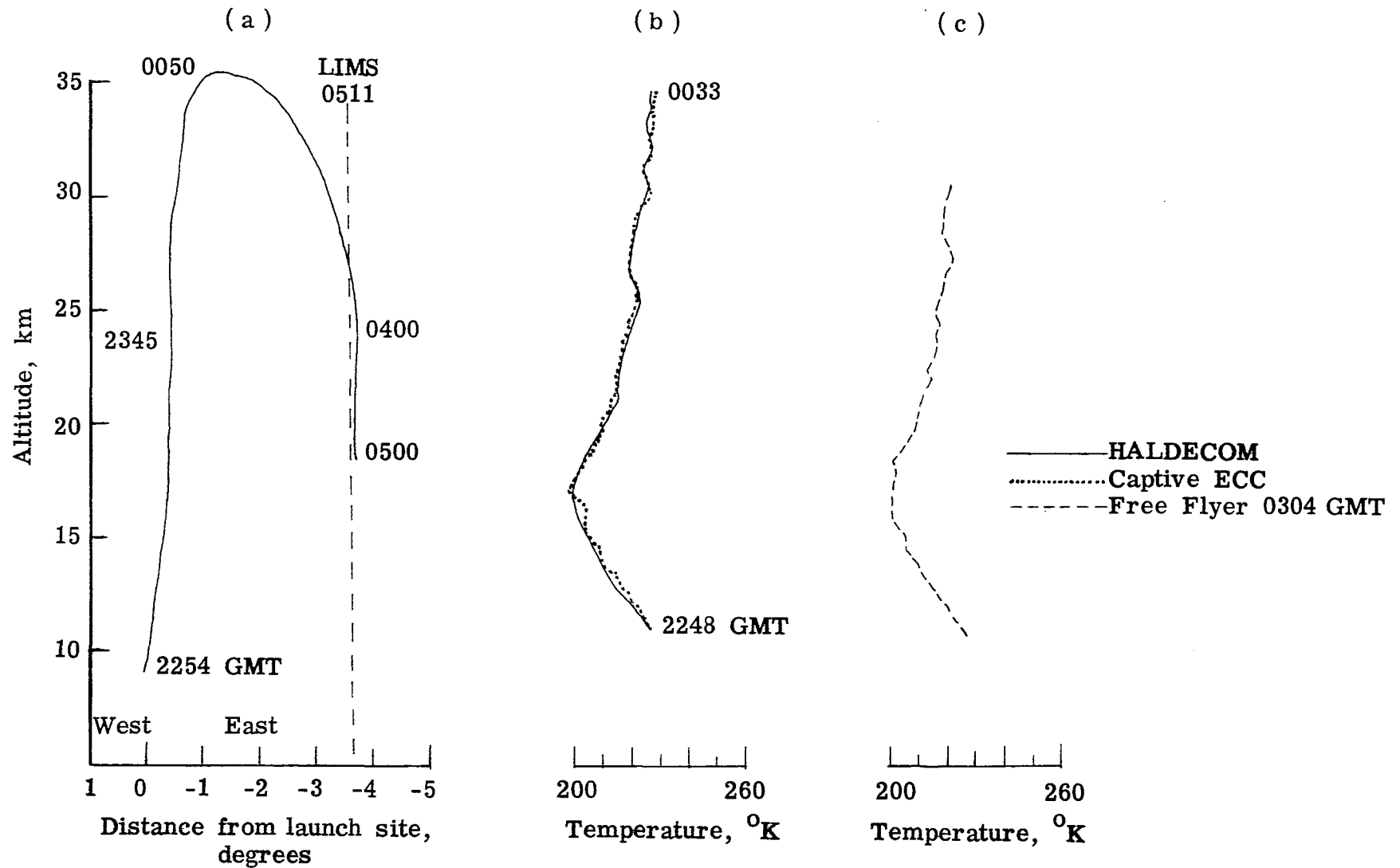


Figure 15.- For the October 30, 1978, LIP flight, shown are the (a) LIP flight trajectory relative to Palestine and the 0511 GMT October 31, 1978, LIMS overpass, (b) ascent HALDECOM and captive ECC temperature profiles, and (c) representative descent temperature profile obtained from a free flyer launched at 0304 October 31, 1978, from Palestine.

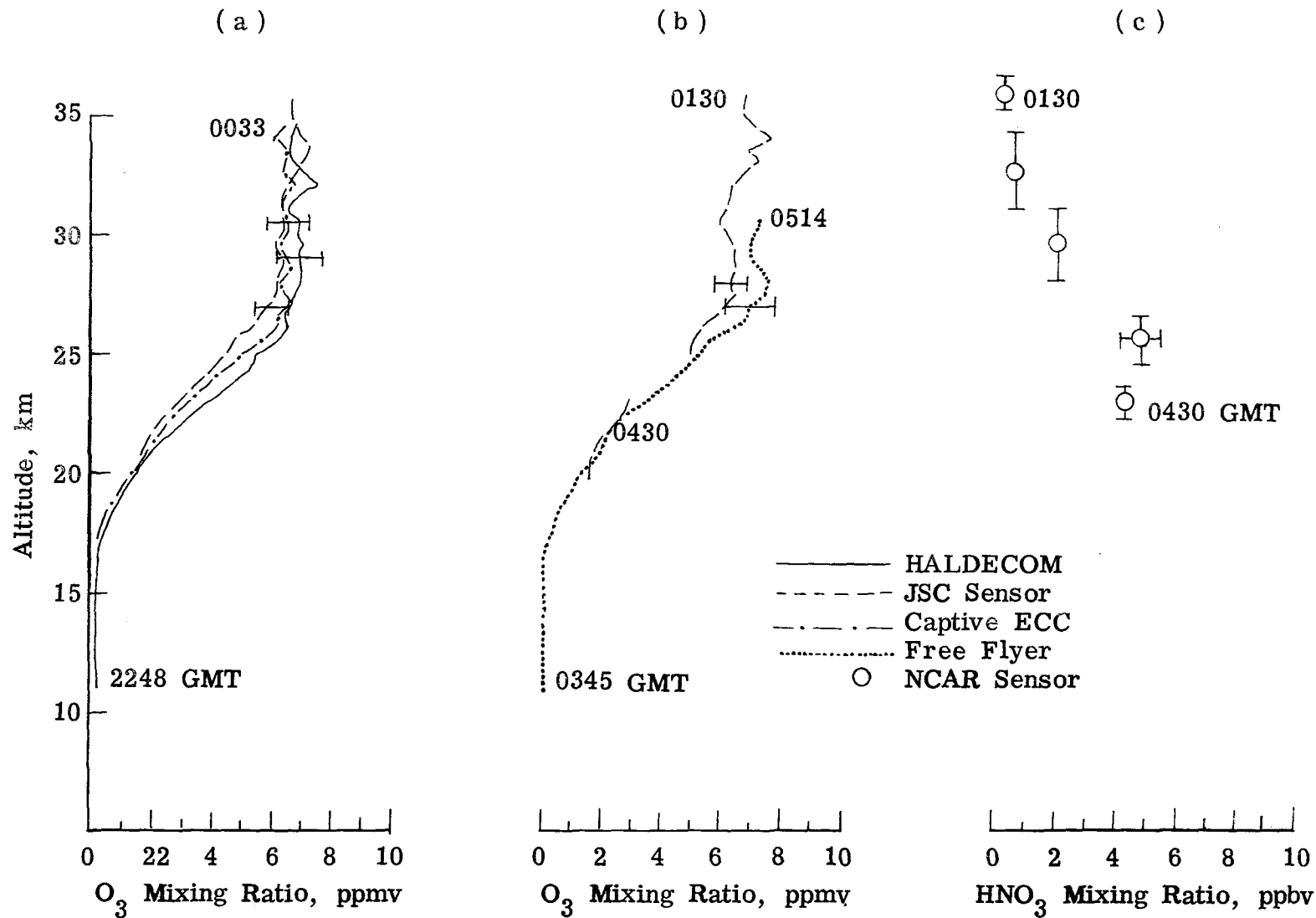


Figure 16.- For the October 30, 1978, LIP flight, shown are the (a) ascent HALDECOM, captive ECC, and JSC photometer O₃ mixing ratios, (b) descent photometer and free flyer O₃ mixing ratios, and (c) NCAR chemical absorption filter HNO₃ mixing ratios.

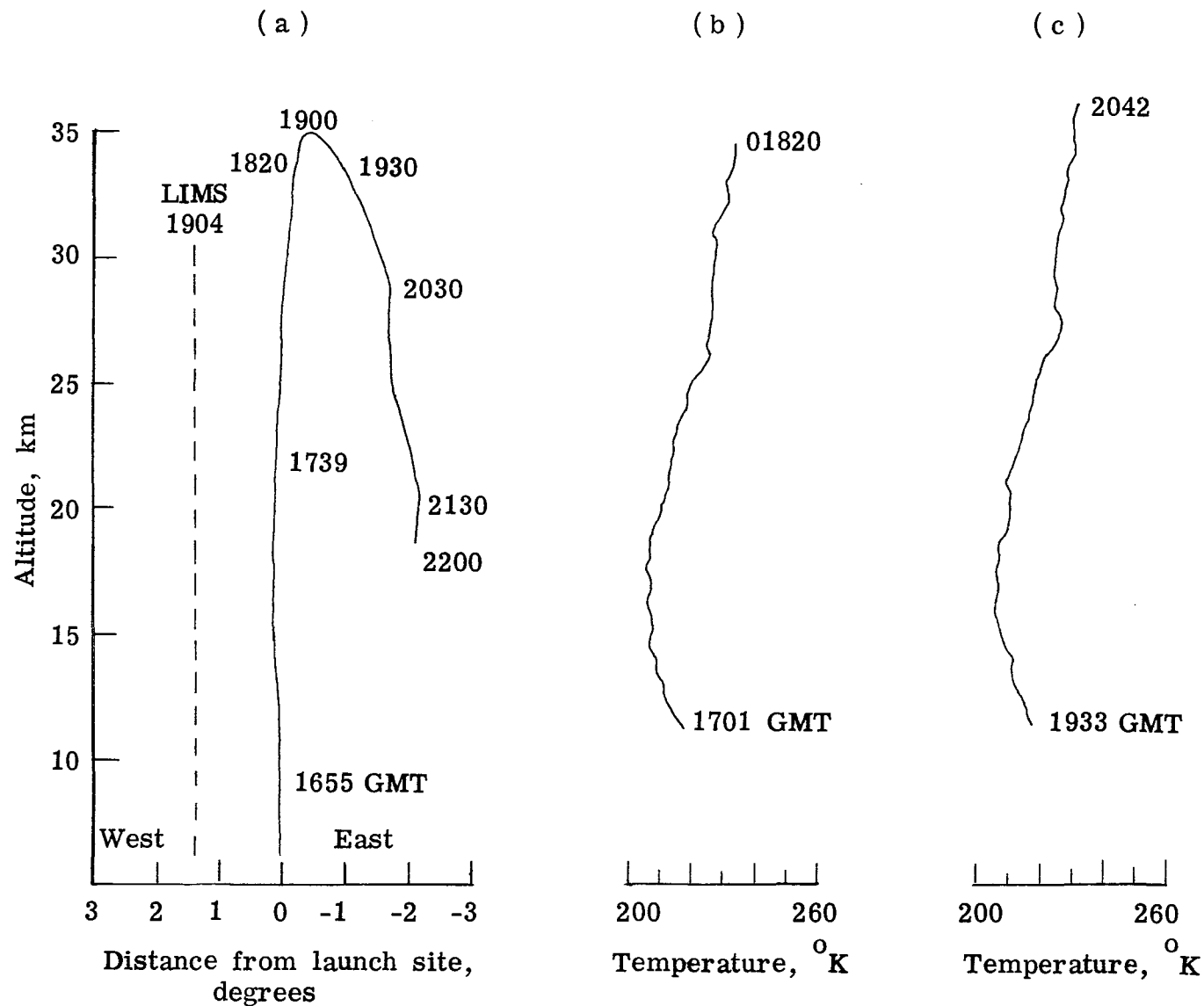


Figure 17.- For the November 8, 1978, LIP flight, shown are the (a) flight trajectory relative to Palestine and the 1904 GMT LIMS overpass, (b) the ascent HALDECOM temperature profile, GMT and (c) a representative descent temperature profile obtained from a free flyer launched at 1851 GMT from Palestine.

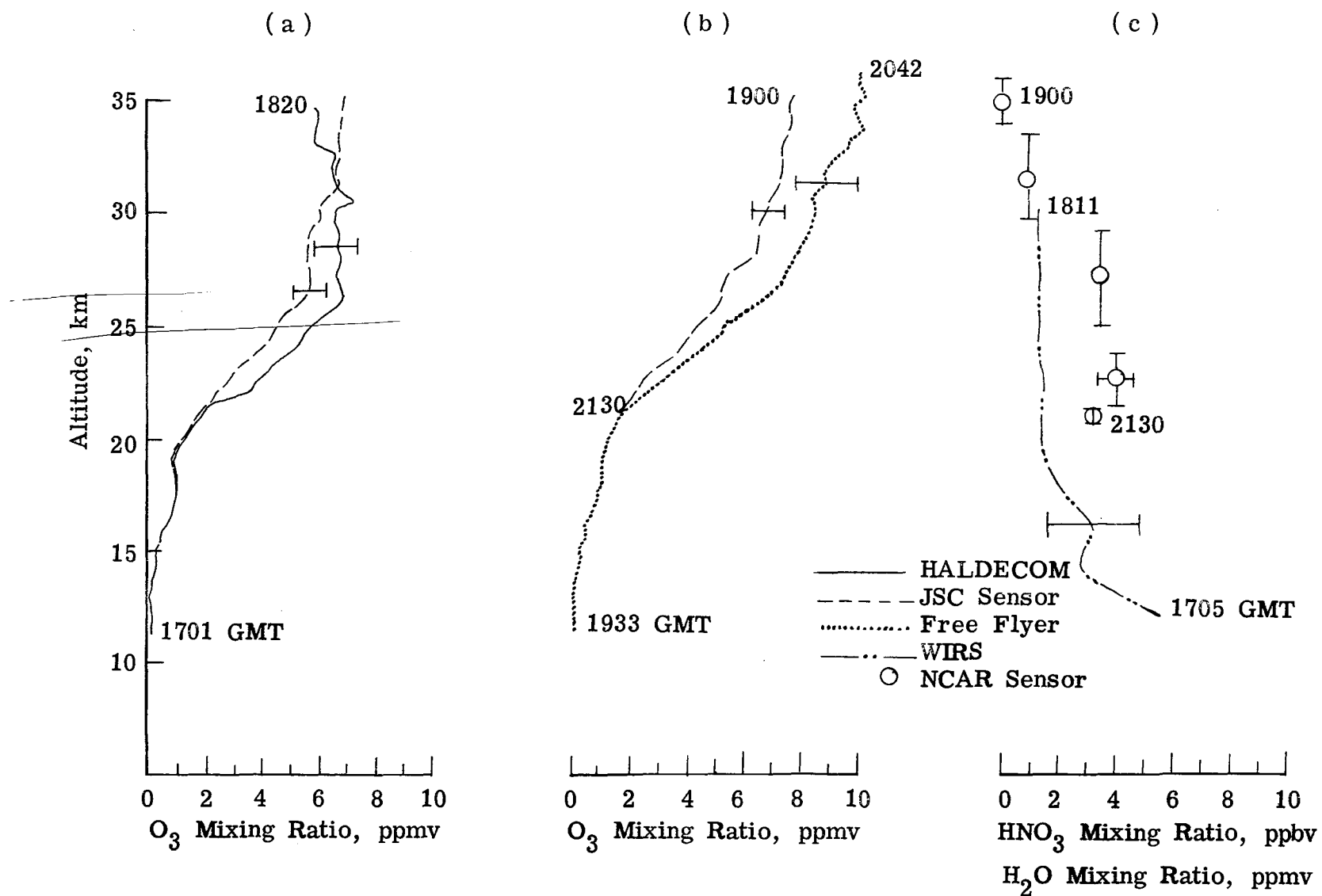


Figure 18.- For the November 8, 1978, LIP flight, shown are the (a) ascent HALDECOM and JSC photometer O_3 mixing ratios, (b) descent photometer and free flyer O_3 mixing ratios, and (c) NCAR HNO_3 and WIRS H_2O vapor mixing ratios.

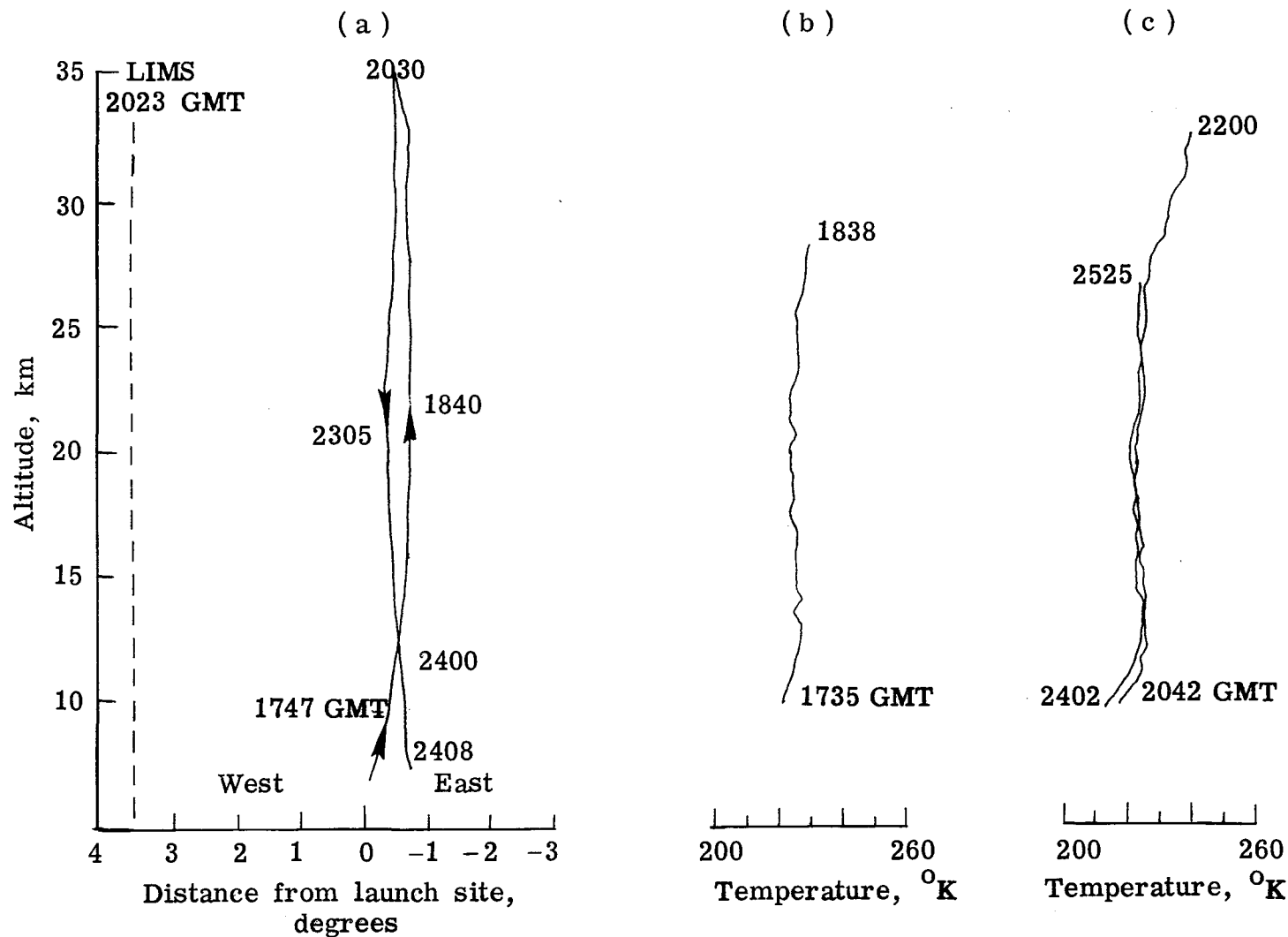


Figure 19.- For the February 8, 1981, LIP flight, shown are the (a) flight trajectory relative to Cold Lake and the 2024 GMT LIM overpass, (b) representative ascent temperature profiles from free flyers launched at 1702 and 2007 GMT from Primrose, and (c) representative temperature profiles from free flyers launched at 2007 and 2327 GMT from Primrose.

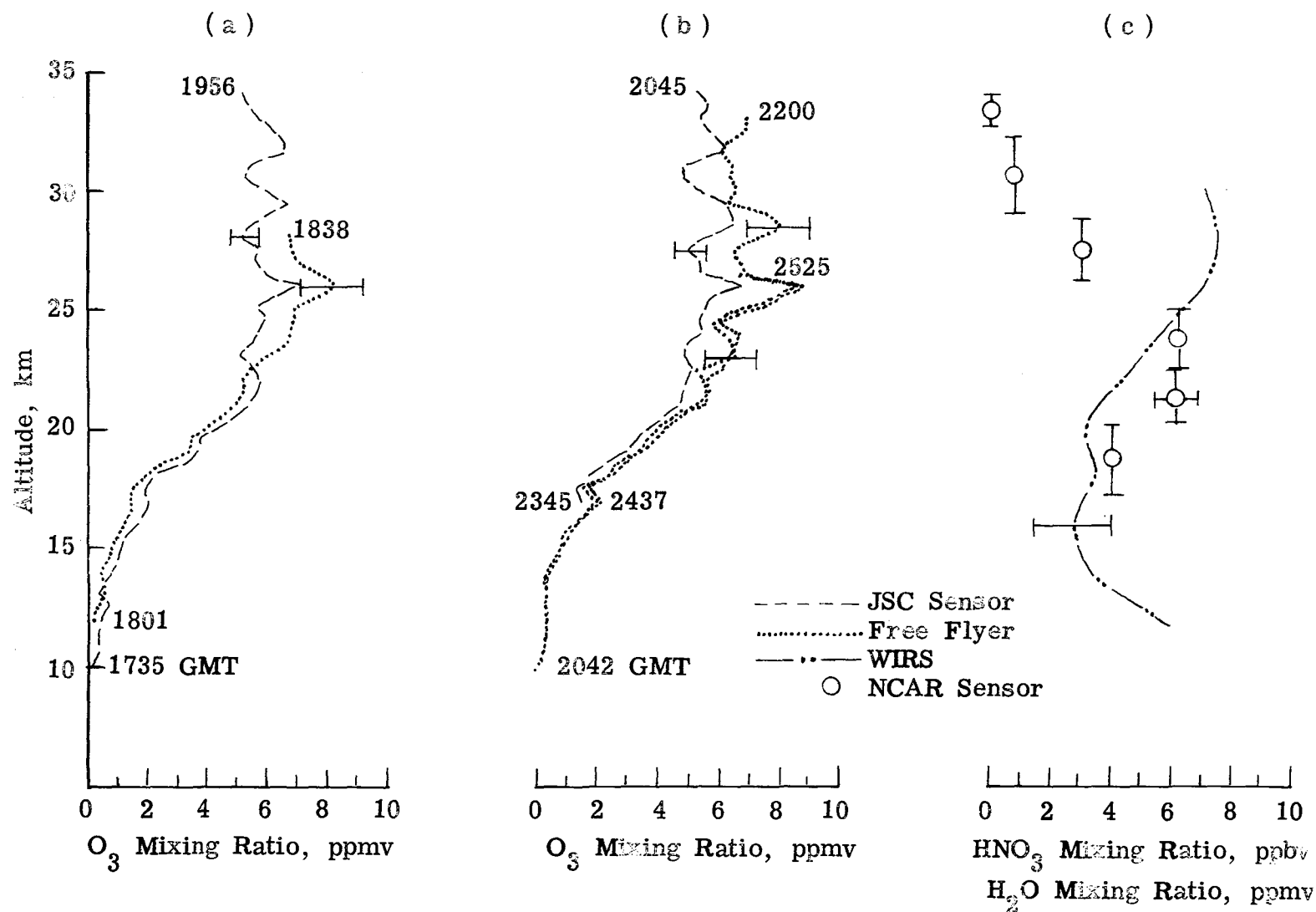


Figure 20.- For the February 8, 1979, LIP flight, shown are the (a) ascent JSC photometer and free flyer O_3 mixing ratios, (b) descent meter and free flyers O_3 mixing ratios, and NCAR HNO_3 and WIRS H_2O vapor mixing ratios.

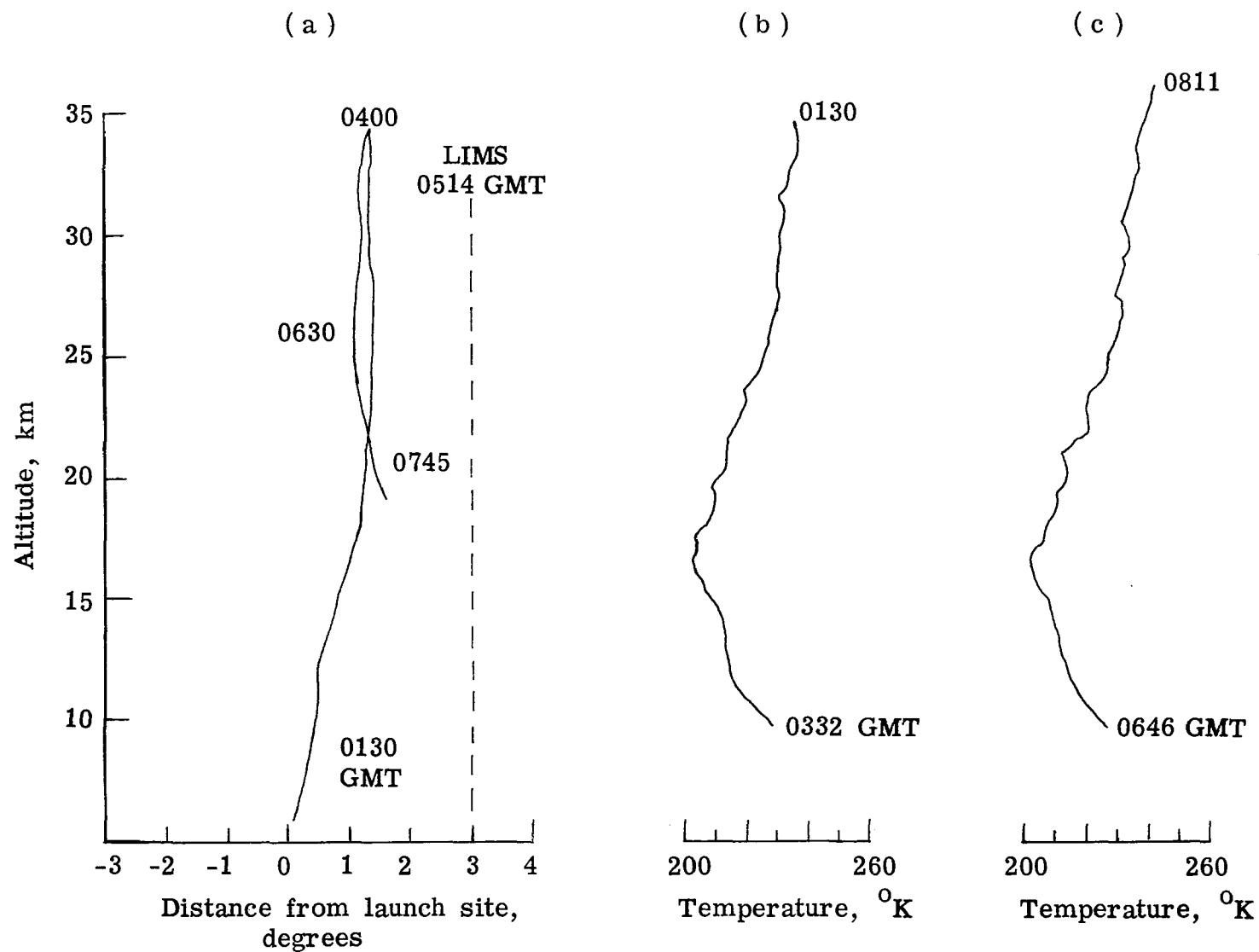


Figure 21.- For the April 6, 1979, LIP flight, shown are the (a) flight trajectory relative to Palestine and the 0514 GMT overpass, (b) ascent HALDECOM temperature profile, and (c) representative descent temperature profile from a free flyer launched at 0613 GMT from Palestine.

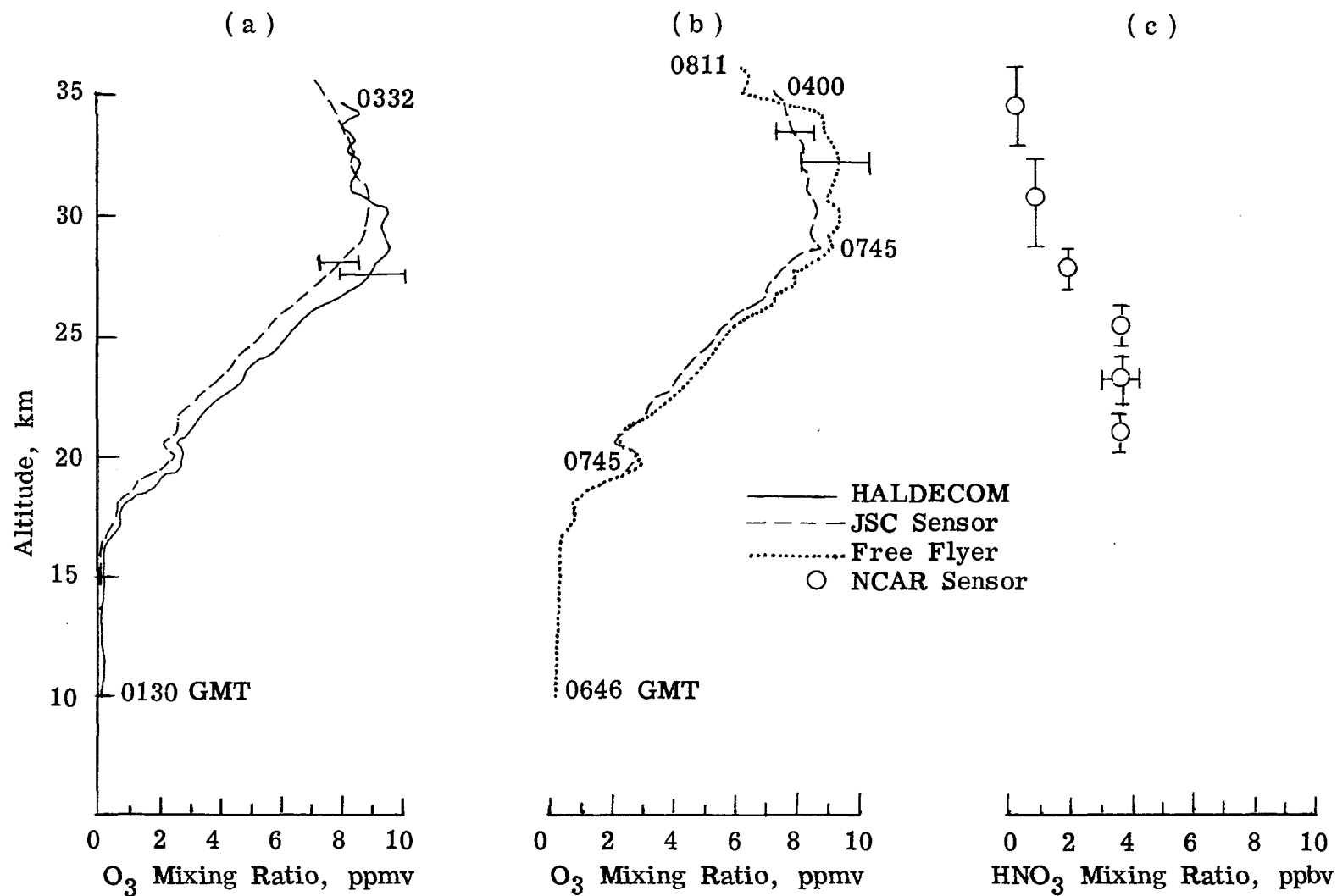


Figure 22.- For the April 6, 1978, LIP flight, shown are the (a) ascent HALDECOM and JSC photometer O₃ mixing ratios, (b) descent photometer and free flyer O₃ mixing ratios, and (c) NCAR HNO₃ vapor mixing ratios.

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|---|--|--|--|---|--|
| 1. Report No. NASA TM-83259 | | 2. Government Accession No. | | 3. Recipient's Catalog No. | |
| 4. Title and Subtitle LIMS Instrument Package (LIP) Balloon Experiment - Nimbus 7 Satellite Correlative Temperature, Ozone, Water Vapor, and Nitric Acid Measurements | | | | 5. Report Date February 1982 | |
| | | | | 6. Performing Organization Code 665-10-40-03 | |
| 7. Author(s) Robert B. Lee, III ¹ , Bruce W. Gandrud ² , Donald E. Robbins ³ , Laurence C. Rossi ⁴ , and Nigel R. W. Swann ⁵ | | | | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va 23665 | | | | 10. Work Unit No. | |
| | | | | 11. Contract or Grant No. | |
| 12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546 | | | | 13. Type of Report and Period Covered Technical Memorandum | |
| | | | | 14. Sponsoring Agency Code | |
| 15. Supplementary Notes ¹ Langley Research Center; ² National Center for Atmospheric Research; Boulder, CO 80303; ³ NASA Lyndon B. Johnson Space Center, Houston, TX 77058; ⁴ NASA Wallops Flight Center, Wallops Island, VA 23337; and ⁵ National Physical Laboratory, Middlesex, UNITED KINGDOM, TW11 OLW | | | | | |
| 16. Abstract Between June 1978 and April 1979, the NASA Limb Infrared Monitor of the Stratosphere (LIMS) Instrument Package (LIP) balloon experiment was used to obtain correlative temperature, ozone, water vapor, and nitric acid data at altitudes between 10 and 36 kilometers. These data were obtained in order to assess the performance of the LIMS sensor flown on the Nimbus 7 Satellite. The LIP consisted of the NASA Wallops Flight Center modified electrochemical concentration cell ozonesonde, the NASA Lyndon B. Johnson Space Center ultraviolet absorption photometer for ozone, the British National Physical Laboratory water vapor infrared radiometric sonde, the NCAR chemical absorption filter instrument for nitric acid vapor and the Institute D'Aeronomie Spatiale de Belgique infrared radiometer for nitric acid vapor. This document contains descriptions of the LIP, its correlative sensors, and the resulting data obtained from an engineering and four correlative flights which were launched from Palestine, Texas and Cold Lake, Alberta, Canada. | | | | | |
| 17. Key Words (Suggested by Author(s)) <u>Absorption, balloon</u> <u>emission, infrared, LIMS, nitric acid, Nimbus</u> <u>7, ozone, ozonesonde, photometer, radiometer,</u> <u>radiosonde, stratosphere, temperature, and</u> <u>water vapor</u> | | | | 18. Distribution Statement Unclassified - Unlimited Subject Category 45 | |
| 19. Security Classif. (of this report) Unclassified | | 20. Security Classif. (of this page) Unclassified | | 21. No. of Pages 40 | |
| | | | | 22. Price* A03 | |

